UTILIZATION OF DOMESTIC WASTEWATER FOR IRRIGATION IN DODOMA AND MOROGORO REGIONS, TANZANIA

BY

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ABSTRACT

This study was undertaken to investigate the extent of domestic wastewater utilization for irrigation in Dodoma and Morogoro regions. Cross-sectional study was conducted from June, 2008 to February, 2009 in urban and per-urban areas using structured questionnaires from a sample of 200 respondents. Heavy metal contents in wastewater, sediments and tomatoes were analysed using the atomic absorption spectrophotometer. The study showed that the major sources of wastewater generation were residential, commercial and institutional areas. Wastewaters generated from various sources were treated by Waste Stabilization Ponds (WSPs) system that uses natural factors. The study found that 90% of the 112 households using wastewater and 85% of the 88 households not using the resource indicated effluents from WSPs as main and reliable source of water for irrigation. Informal flood irrigation was practiced by farmers using wastewater however without wearing protective devices. Wastewater utilization in agriculture was accepted by 97.3% of farmers using wastewater and 64.8% of farmers not using it and the difference was significant ($p<0.01$). The main crops cultivated using treated wastewater included maize, rice and vegetables. Important factors that influenced utilization of wastewater in agriculture included awareness of the benefits of using wastewater, average income accrued from agricultural activities, paddy production per acre, distance to main water source, location of farmers and minimal use of fertilizer in the field. Wastewater utilization improves livelihoods of farmers and food security and serves as a source of employment. The concentrations of heavy metals in tomatoes irrigated with wastewater after the maturation pond were lower than the recommended values by the World Health Organisation (WHO, 2008) that demonstrated no health risks to consumers. Based on the findings from this study it is recommended that Urban Water and Sewerage Authorities should improve service delivery on water and sewerage and encourage people to subscribe

to sewerage services; wastewater use in agriculture be included in the district plans; the country should develop guidelines, policies and practices for safer wastewater use; and research on microbial analysis and on organic pollutants be conducted to establish evidence of health effects associated with the use of wastewater in agriculture.

DECLARATION

I, Kilobe Benedict Makono, do hereby declare to the Senate of Sokoine University of Agriculture, that this thesis is my original work and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

28·3·2012

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LIST OF ABBREVIATIONS

AIDS	Acquired Immune Deficiency Syndrome
ANOVA	Analysis of Variance
BDL	Below Detection Limit
CSRP	Civil Service Reform Programme
DAWASA	Dar es Salaam Water Supply and Sewerage Authority
DAWASCO	Dar es Salaam Water and Sewerage Corporation
FAO	Food and Agriculture Organization
FGDs	Focus Group Discussions
HH	Household
HIV	Human Immunodeficiency Virus
HSD	Honestly Significant Difference
IRDP	Institute of Rural Development Planning
IWMI	International Water Management Institute
LGAs	Local Government Authorities
MARL	Maximum Acceptable Residue Level
M	Mean
MDGs	Millennium Development Goals
NSGRP	National Strategy for Growth and Reduction of Poverty
OLS	Ordinary Least Square
PSD	Population Strategy Programme
SADC	Southern Africa Development Community
SEAMIC	Southern and Eastern Africa Mineral Centre
SD	Standard Deviation
SPSS	Statistical Package for Social Science

SUA	Sokoine University of Agriculture
TBS	Tanzania Bureau of Standards
TDI	Total Daily Intake
Tshs	Tanzanian Shillings
UK	United Kingdom
UN	United Nations
UNDP	United Nations Development Programme
URT	United Republic of Tanzania
USA	United States of America
US$	United States dollar
UWSAs	Urban Water and Sewerage Authorities
WHO	World Health Organisation
WSPs	Wastes Stabilization Ponds

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Water resource is an important catalyst for accelerating economic and social development (URT, 2002a). The resource is an essential component for sustaining life, maintaining health and ensuring sustainable livelihoods. The United Nations (UN) general comment on the right to water identifies access to water as a human right at which governments require actions to fulfill it (Howard and Obika, 2003). Thus, water scarcity is a major constraint to economic and social development and sustainability of the agricultural sector, particularly in areas that face limited amount of water in terms of quality and quantity (Madulu, 2000; Maher *et al.*, 2008).

In many parts of the world, freshwater is already scarce and the value of freshwater will further increase in regions which experience water scarcity and high population growth (Pereira *et al.*, 2002; WHO, 2006a, b, c). The growing water scarcity is a result of increasing multi-sectoral demands of the rapidly growing population (URT, 2002a; WHO, 2006b). In terms of utilization, agriculture is the single largest user of freshwater in the world, accounting for nearly 70% of all extractions worldwide (FAO, 2002; Pereira *et al.*, 2002; Brown, 2003 cited by Buechler *et al.*, 2006; Rashid-Sally and Jayakod, 2008). As freshwater becomes increasingly scarce due to population growth, urbanization and climate change, the use of wastewater is becoming more important (Ensink *et al.*, 2004a; WHO, 2006b, d).

The use of wastewater in agriculture started in the 19^{th} century when cities in Europe and North America introduced the water carriage system for domestic wastewater

(Ensink *et al.*, 2004a). Large sewage farms, as they were called, were established in the United Kingdom (UK), United States of America (USA), France, China and Germany, followed by India, Australia and Mexico (Mara and Cairncross, 1989). The main purpose of establishing these farms was to prevent the contamination of rivers and to improve soil fertility (Mara and Cairncross, 1989). Most of these sewage farms were abandoned at the beginning of the 20th century for a number of reasons, notably the need for more land for expanding cities, increased awareness of adverse human health impacts, the introduction of chemical fertilizers and development of wastewater treatment technologies (Ensink *et al.*, 2004a).

However, increasing water scarcity and stress due to rapid population growth and climate change and degradation of freshwater resources resulting from improper disposal of wastewater in urban areas have contributed to increased wastewater use both in developing and industrialized countries (Ensink *et al.*, 2004a; Buechler *et al.*, 2006; Rashid-Sally and Jayakod, 2008). More to that, a growing recognition of the resource value of wastewater and the Millennium Development Goals (MDGs), especially the goals for ensuring environmental sustainability and eliminating poverty and hunger have increased the use of wastewater for irrigation globally (WHO, 2006a, b, d).

Wastewater is an important source of water for many farmers in arid and semi-arid climates and sometimes it is the only water source available for agriculture (Buechler *et al.*, 2006; WHO, 2006a, b, c). Wastewater use for irrigation generates livelihoods for farmers, agricultural laborers, produce transporters, and produce vendors (Buechler *et al.*, 2006; Rashid-Sally and Jayakod, 2008). More use of wastewater occurs in urban and peri-urban agriculture because this is where large amount of wastewater are generated and the demand of food is high (WHO, 2006a). In addition, there is accessible and reliable market for the farm products with low costs for transportation.

Urban Water and Sewerage Authorities (UWSAs) are water entities established in 19 regional centers of Tanzania Mainland (URT, 2007; 2009a). The UWSAs were established by Act No. 8 of 1997 with the obligation of supplying adequate potable water and providing sewerage services to customers at affordable cost (URT, 2007). In addition, the Dar es Salaam Water Supply and Sewerage Authority (DAWASA) was established under waterworks Act No.20 of 2001 with the obligation of supplying water to the City of Dar es Salaam and parts of Coast region, including Bagamoyo and Kibaha Townships (URT, 2009a). In 2005, operations of Dar es Salaam water supply systems were transferred to Dar es Salaam Water and Sewerage Corporation (DAWASCO). Out of the 19 UWSAs established in Tanzania mainland, nine have Waste Stabilization Ponds (WSPs) which are used to treat wastewater before discharging into receiving water bodies including lakes, rivers and ground (URT, 2007). Table 1 shows the estimated quantity of wastewater produced in nine urban centers of Tanzania in 2006.

Table 1: Estimated quantities of wastewater produced in urban centers in Tanzania

Name of Urban Center	Quantity produced (m^3 /year)
Arusha	1 720 000
Bukoba	1 800 000
Dodoma	4 905 600
Morogoro	7 002 760
Moshi	3 850 000
Mbeya	7 087 998
Mwanza	11 656 000
Tabora	3 680 658
Tanga	812 000

Source: URT (2007).Urban Water and Sewerage Authorities Annual Report

Expansion of urban population and increased coverage of domestic water supply and sewerage give rise to greater quantities of municipal wastewater. Available statistics reported by DAWASCO (2010), indicated that the volume of sewage carried in sewers in Dar es Salaam City from July 2009 to June 2010 was 19 717 000 m^3. Volume of sewage treated in seven (7) out of eight (8) wastewater treatment ponds was 20 133 000 m^3/year. This volume is about four (4) times the quantity of wastewater generated in Dodoma urban center.

1.2 Problem Statement

Tanzania faces a water stress situation in some parts of the country, as water demands exceed the available resources thereby raising concerns on its use, quantity and quality (URT, 2008). Available statistics show that in 1999, the availability of renewable freshwater resources, both surface and groundwater was estimated to be about 2700m^3/capita/year (URT, 2008). By 2002, this estimate was reduced to 2300m^3/capita/year due to increased population alone. This figure is significantly above the level of 1700m^3/capita/year set by United Nations as denoting water stress, or 1000m^3/capita/year denoting water scarcities (URT, 2008). However, due to projected population growth alone, Tanzania's annual water rate is projected to drop to 1500m^3/capita/year by 2025, thus categorizing the country as water stressed (URT, 2008). This situation calls for adoption of measures to improve efficiencies in water use aimed at making more water available to meet demands. Measures to be taken may include recycling of used water and utilization of wastewater generated in urban areas for agricultural purposes.

Urban areas of Tanzania are experiencing rapid expansion coupled with rapid population growth of 2.9% per annum (URT, 2003a; URT, 2005). It is estimated that about 80% of water supplied in urban areas of Tanzania result into the production of wastewater (URT, 2002a). Little is known about the extent of domestic wastewater utilization in urban and peri- urban agriculture in Tanzania. Previous studies by Kinyashi and Obongoya (2006) on wastewater concentrated on the assessment of environmental effects of waste stabilization ponds on residents of peri urban areas. Equally important, the information on sources of domestic wastewater generated in urban and peri-urban areas of Tanzania and factors influencing wastewater utilization in agriculture are not documented. Furthermore, benefits derived from wastewater utilization in agriculture and the impacts of wastewater utilization on environment and human health are not well documented.

1.3 Justification of the Study

Despite the vast amount of research on wastewater utilization in urban and peri-urban agriculture in different parts of the world, very little is known on the extent of domestic wastewater utilization in Tanzania (Kinyashi and Obongoya, 2006). Generally, there is minimum information on the socio economic benefits and the problems associated with use of wastewater in agriculture although it is clear that some of the urban dwellers use wastewater as an urban livelihood strategy.

Municipalities, water boards and city/district planners often ignore this important economic activity for urban dwellers and they do not include it in their planning (Buechler *et al.*, 2006). This might be attributed to the lack of information on the extent of wastewater utilization in urban and peri-urban agriculture. The use of wastewater in agriculture has the potential to affect poverty positively through improved household food security and nutritional variety, which reduces malnutrition and increased household income from sale of surplus crops. These are among the targets in the National Strategy for Growth and Reduction of Poverty (NSGRP) (URT, 2005).

The study therefore, was worth undertaking as it sheds light on the potentials of the resource in improving the livelihoods of the urban and peri-urban people through income generation from agricultural activities; increasing household food security and as a source of employment to urban and peri-urban people. Similarly, the study documents the type of crops grown in the study areas and associated irrigation practices. Environmental problems associated with wastewater utilization in agriculture are also identified. Furthermore, in order to minimize negative impacts of wastewater utilization on environment and the health risks for field workers (farmers) and consumers of the products while maximizing the benefits of wastewater resource for crop production, the study document the current status of wastewater disposal practices in the study areas, the quality of water resource used for irrigation, heavy metal concentration in sediments and tomatoes irrigated with wastewater. The findings of the study form a basis for recommendations to policy makers and UWSAs through policy brief on safe use of wastewater in agriculture.

This study provides information on the benefits of wastewater utilization in urban and peri-urban agriculture in Tanzania, in view to provide evidence for policy makers on the value and potential of this neglected and wasted resource. Lastly, the findings of the study shed light on the contribution of domestic wastewater in achieving some of the goals outlined in the NSGRP.

1.4 Objectives

1.4.1 Overall objective

The overall objective of this study was to investigate the extent of domestic wastewater utilization for irrigation in Dodoma and Morogoro regions.

1.4.2 Specific objectives

The specific objectives of this study were to:

(i) Assess sources of domestic wastewater production in the study areas

(ii) Examine the extent of wastewater utilization in agriculture in the study areas

(iii) Determine factors influencing utilization of wastewater in the study areas

(iv) Identify benefits of using wastewater in agriculture

(v) Assess the quality of water, sediments and plants irrigated with wastewater

1.5 Research Questions

In order to achieve the intended study objectives, the study was guided by the following research questions:

(i) What are the main sources of wastewater production?

(ii) What are the uses of wastewater coming from waste stabilization ponds?

(iii) Which factors determine wastewater utilization?

(iv) What are the benefits of using wastewater?

(v) What is the quality of water, sediments and plants irrigated with wastewater?

1.6 Conceptual Framework

Figure 1 represents the conceptual framework for the study on wastewater utilization. The conceptual framework is a narrative outline presentation of variables to be studied and relationship between and among variables. It is worth to note that wastewater utilization which is the dependent variable was assumed to be influenced by a set of independent variables. The independent variables assumed in this study included household variables, institutional factors and socio-economic variables.

Household variables: Wastewater utilization depends on availability of water supply, household location and the distance travelled to the main water sources. With the increase in urban population, the quantities of wastewater produced also increases. As the amount of freshwater increasingly becomes scarce due to population growth and climate change, use of wastewater produced in urban and peri-urban centres may become part of the solution to cope with water scarcity especially in agriculture.

Institutional factors: Utilization of wastewater is influenced by interplay of institutional factors which include wastewater disposal practices, quality of water and soil exposed to wastewater, existence of bylaws and policies governing utilization of wastewater in urban and peri-urban areas. Wastewater from cities is discharged into ground and surface waters such as lakes, rivers and treatment facilities which are sometimes poorly managed. Use of untreated wastewater may, therefore, lead to the accumulation of industrial contaminants in aquatic vegetables and present a food safety risk. To protect consumers from the potential adverse health impacts of wastewater use in agriculture, the quality of wastewater, sediments and produce must be determined. Comparing the results and the recommended values by the World Health Organization (WHO, 2006b; 2008) safe use of wastewater may lead to beneficial use of important resource.

Socio-economic variables: Utilization of wastewater depends on the ability to possess land close to WSPs for agricultural activities. Farmers owning land or have ability to hire plots near WSPs have higher chances of utilizing wastewater in agriculture. Increase of income for sales of surplus crops and vegetables irrigated with treated wastewater and minimal utilization of fertilizer are also critical factors which may influence utilization of wastewater. Moreover, increase in crop production per acre is assumed to have an influence on wastewater utilization in urban and peri-urban agriculture. Number of years that farmers have engaged in agriculture could directly influence use of wastewater as farmers are expected to have more experience in their environment, cultivation and are able to assess the benefits of using the resource. Higher Level of education are expected to have negative influence on the use of wastewater because education level is associated with greater information on health risks once the resource is not well treated.

The background variables namely household head's age, marital status, number of dependants and household size also have an influence on the utilization of wastewater. Furthermore, geographical characteristics which include location of household, rain water pattern, water availability and drought may also influence the use of wastewater. Households located near WSPs and having access to land for cultivation are more likely to use wastewater in irrigating their crops. Areas characterized by seasonal and unreliable rains with a long dry season are expected to influence utilization of wastewater in agriculture.

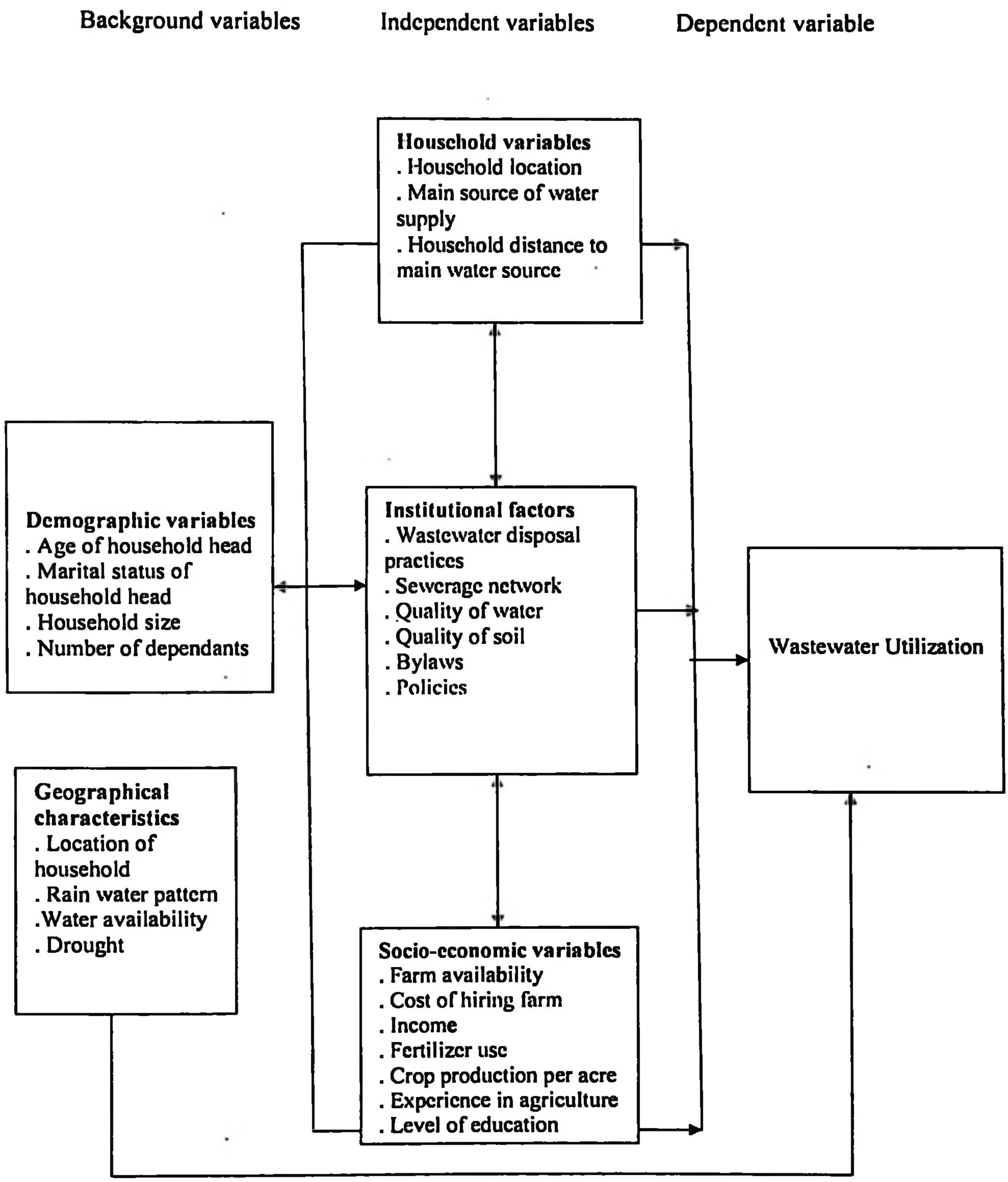

Figure 1: Conceptual framework for examining factors influencing wastewater utilization in urban and peri- urban agriculture

1.7 Organisation of the Thesis

This thesis is organised into five chapters. Chapter one presents the background information for this study, problem statement, justification for undertaking the study, objectives of the study, research questions and conceptual framework. Chapter two presents the induced innovations theory, concepts and definition of wastewater and urban agriculture, use of wastewater for irrigation, the potential and problems associated with its utilization, heavy metals uptake by plants and policy aspects in Tanzania in relation to wastewater use. Chapter three describes the methodology adopted for this study. Chapter four presents and discusses the results of the study. Finally, Chapter five gives conclusions and recommendations based on the major findings of the study.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Induced Innovations Theory

Innovations are simply defined as new methods, customs or devices that are used to perform a certain task (Sunding and Zilberman, 2000). The theory of induced innovations seeks to explain the path of technological development in agriculture in terms of changing relative factors scarcities over time (Sunding and Zilberman, 2000). Induced innovation theory of Hayami and Ruttan (1984) state that the technological innovation and institutional change take place to economize on scarce resource. The theory is based on the assumption that scarcity of resources and economic opportunities lead to search for new innovation.

Hayami and Ruttan (1985), formalized and empirically verified their theory of induced innovation that closely linked the emergency of innovations with economic conditions. They argued that the search for new innovations is an economic activity that is significantly affected by economic conditions. New innovations are more likely to emerge in response to scarcity of resources and economic opportunities. They gave an example of Israel where drip irrigation and other water serving technologies are often developed to cope with water scarcity.

The work of Binswanger and McIntire (1987), on the evolution of agricultural systems supports the induced innovation theory. Early human groups, consisting of a relatively small number of members who could own large areas of land were hunters and gathers. An increase in population led to evolution of agricultural systems. The transition to more intensive farming systems that used crop rotation and fertilization occurred as population density increased further. The need to overcome diseases and improve crop production led to the development of innovations in pest control and breeding.

While scarcity of resources and economic opportunities represent potential demand that is, in most cases, necessary for the emergence of new innovations, Hayami and Ruttan (1985) argued that a potential demand is not sufficient for inducing innovations. In addition to demand, they explained that the emergence of new innovations requires technical feasibility and new scientific knowledge that will provide the technical base for the new technology. Thus the potential demand and the appropriate knowledge base are integrated with the right institutional set up, and together they provide the background for innovation activities (Hayami and Ruttan, 1985).

Cities in developing countries are experiencing unparallel growth and rapidly increasing water supply and sanitation coverage that will continue to release growing volumes of wastewater (Buechler and Scott, 2006). Freshwater in many parts of the world is already scarce (Pereira *et al.*, 2002; WHO, 2006a, b). The need to overcome the increasing scarcity of water resource, especially in agriculture and make use of the available wastewater generated in urban and peri-urban areas requires technical feasibility and scientific knowledge on the extent of its utilization in agriculture (Hayami and Ruttan, 1985).

2.2 Definition of Wastewater

Wastewater is defined as liquid waste discharged from homes, commercial premises and similar sources to individual disposal systems or to municipal sewer pipes, and which contains mainly human excreta and used water (WHO, 2006b). In this definition, wastewater is regarded as water discharged after being used or produced by a process and which is of no further immediate value to that process. When produced mainly by household and commercial activities, it is called domestic or municipal wastewater (WHO, 2006b, c, d). In this study, domestic wastewater means domestic sewage or wastewater which does not contain industrial effluents at levels that could pose threats to the functioning of sewerage system, treatment plant, public health and the environment.

2.3 The Concept and Definition of Urban and Peri-Urban Agriculture

Urban agriculture is one of the most important informal activities chosen by urban dweller in many towns and cities. It involves crops and livestock production and sometimes it may also include agro-forestry and fuel production. It is practiced both within the urban boundary and its periphery. The majority of people involved in urban and peri urban agriculture are the urban poor (Mlozi, 1995).

Madden and Chaplowe (1997), define urban agriculture as the practice of crop cultivation and livestock raising within the boundaries or the immediate periphery of a city. The choice of what to produce and how to produce is determined by the culture, traditions, market, water supply, rainfall, climate, exposure to sun, soil condition, plot size and distance from home (Madden and Chaplowe, 1997). UNDP (1996), defines urban agriculture as an industry that produces food largely in response to daily demand of consumers in urban and peri-urban areas. The process of food production involves application of intensive production methods using and recycling natural resources and urban wastes to yield a diversity of crops and livestock (UNDP, 1996). Mlozi (1999), define urban agriculture as the raising of animals such as daily cattle, poultry, pigs and goats in urban areas. It also involves growing of vegetables and field crops in areas declared urban by the United Republic of Tanzania under the Town and Country Planning Ordinance CAP.138 of 1956 reviewed in 1991 (Mlozi, 1999). Crops cultivated and livestock keeping in urban and peri-urban areas are both for domestic consumption and sale for the purpose of improving the livelihood (Mlozi, 1995, 1999). In this context, urban and peri-urban agriculture is viewed as an activity which involves growing, processing and distribution of food and other products through intensive plant cultivation and animal husbandry in and around cities (UNDP, 1996; Mlozi, 1999).

It is evident that urban and peri-urban agriculture in Tanzania play an important role in employment creation, income and food supply. Mlozi (1995) explained that urban agriculture provides jobs for the poor and income for the marginalized groups such as women, youth and the elder population. Urban agriculture provides nutrition and it improves the urban environment by using the organic solid and liquid wastes of the city and helps to achieve optimum land utilization (Buechler *et al.*, 2006).

2.4 Categories and Characteristics of Wastewater

Wastewater can be categorized into two groups namely, domestic and sanitary depending on where they originate (Buechler *et al.*, 2006). Domestic wastewater includes typical wastes generated at household level from the kitchen, bathroom and laundry, as well as any other wastes that people may accidentally or intentionally pour down the drain (Buechler *et al.*, 2006). Sanitary wastewater consists of domestic wastewater as well as those discharged from institutional and commercial buildings (Buechler *et al.*, 2006). According to WHO (2006b, d), domestic wastewater is divided into two categories namely, greywater and blackwater. Greywater includes water from the kitchen, bath and/ or laundry and generally it does not contain significant concentration of excreta. Blackwater includes wastewater from toilets, containing faeces, urine and flushing water.

According to Buechler *et al.* (2006), the characteristics of wastewater discharges vary from location to location depending upon the population size, industrial and commercial activities taking place and land uses. Physically, wastewater is usually characterized by a grey colour, musty odour, a solid content of about 0.1%, and 99.9% water content (WHO, 2006b). The solids can be suspended as well as dissolved. Dissolved solids can be precipitated by chemical and biological processes (WHO, 2006b, d). Chemically, wastewater is composed of organic and inorganic compounds as well as various gases (WHO, 2006b). Organic components may consist of carbohydrates, protein, fats and greases, oils and pesticides while inorganic components may consist of heavy metals, nitrogen, phosphorous, sulfur and toxic compound (WHO, 2006b; Ensink and Van der Hoek, 2008). Under biological characteristics, wastewater contains microorganisms classified as protista, plants and animals (WHO, 2006b; Ensink and Van der Hoek, 2008). The category of protista includes bacteria, fungi, protozoa and algae which are the most important in terms of wastewater treatment using waste stabilization ponds which are recommended for developing countries (Ensink *et al.*, 2007).

2.5 Use of Wastewater for Irrigation

Freshwater is a finite and a vulnerable resource which its sustainability is threatened by human induced activities (URT, 2002a). Increase in population and concurrent growth of economic activities requiring water as an input such as in hydropower generation, irrigated agriculture, industries, domestic, livestock, fisheries and forestry activities have exerted pressure on this finite resource (URT, 2002a). Unreliable rainfall in some areas especially in arid and semi arid areas, multiplicity of competing uses, degradation of sources and water catchments areas have threatened food security, energy production and water use conflicts between sectors of the economy (URT, 2002a;WHO, 2006b).

It has been shown in the previous studies that in many parts of the world there is a gradual decline in availability of fresh water to be used for irrigation (Ensink *et al.*, 2004a; Mapanda *et al.*, 2005; Buechler *et al.*, 2006 and Ensink and Van der Hoek, 2008). The use of urban wastewater in agriculture is seen by many as a vital component of integrated water management to overcome regional and global water scarcity (Scott *et al.*, 2004). In places where wastewater is used for irrigation, community gains value from the crops produced and the improvement in livelihoods. Thus, use of wastewater and other industrial effluents for irrigating agricultural lands is on the rise particularly in peri-urban areas of developing countries (Rattan *et al.*, 2005; WHO, 2006b). A study conducted by Ensink *et al.* (2004b) indicated that untreated wastewater was used for irrigation in over 80% of all Pakistani communities. WHO (2006a) indicated that more than 10% of the world's population consumes various crops irrigated with wastewater.

Irrigation with wastewater occurs either formally or informally depending on the intervention of government or donor agency (Cornish and Kielen, 2004). Cornish *et al.* (1999) explained that formal irrigation occurs when farmers rely on some form of fixed irrigation infrastructure that is designed and operated by the government or a donor agency. Informal irrigation usually is practiced by individuals or groups of farmers without reliance on irrigation infrastructure that is planned, constructed or operated through intervention of a government or donor agency (Cornish *et al.*, 1999).

2.6 Driving Forces behind Wastewater Use

Wastewater is increasingly being used for irrigation in both developing and industrialized countries (Ensink *et al.*, 2004a, b; WHO, 2006a, b; Rashid-Sally and Jayakod, 2008). Increasing multi-sector demands of the rapidly growing population that requires water for human consumptions, institutions and industries has been pointed out to be one of the factors behind increasing wastewater use (Ensink *et al.*, 2004a, b; Rashid-Sally and Jayakod, 2008).

Urban food demand and market incentives favouring production in city proximity (Ensink *et al.*, 2004b; Rashid-Sally and Jayakod, 2008) is another driving force behind the use of wastewater in agriculture. Normally, irrigated fields using wastewater are close to urban centers and hence urban markets. A study done by Ensink *et al.* (2004b) found that proximity of urban markets for the produce resulting from wastewater irrigated fields influenced farmers to utilize wastewater for production of different crops. Being close to the market, farmers are sure of selling fresh produce and hence increase their income. WHO (2006a, b) indicated that the MDGs, especially the goals for ensuring environmental sustainability and eliminating poverty and hunger has contributed toward the rapid increase of wastewater utilization in urban and peri-urban areas of both developing and developed countries. Wastewater makes up an important resource for intensive agricultural production by the urban and rural poor and thereby strengthens their livelihood (WHO, 2006a). In ensuring environmental sustainability, safe use of wastewater contributes to less pressure on freshwater resources which are scarce in many parts of the world and reduces the health risks for downstream communities (WHO, 2006a, b).

Lack of alternative water due to increasing water scarcity and stress, and degradation of freshwater resource resulting from improper disposal of wastewater (WHO, 2006b; Rashid-Sally and Jayakod, 2008) is another driving force behind increasing wastewater use in agriculture.

Demographic variables such as age, education level, houschold size and marital status play a big role in adopting a new technology in agriculture (Simon, 2006). Socio-economic variables and geographic characteristics may have an influence on the use of wastewater in agriculture. However, the literature reviewed did not address these as factors influencing wastewater utilization for farmers who have access to the resource.

2.7 Contribution of Wastewater to Food Security

Use of wastewater in agriculture is an important livelihood for urban poor and a source of fresh produce to urban centres (Scott *et al.*, 2004; Buechler *et al.*, 2006). Studies conducted by Ensink *et al.* (2004a) and Buechler and Devi (2003) indicate that use of wastewater in agriculture contribute to household food security. A national wide survey in Pakistan showed that about 25% of all vegetables grown in the country were irrigated using untreated urban wastewater (Ensink *et al.*, 2004a). These vegetables were cultivated close to the urban markets and thus they were considerably cheaper than the vegetables imported from different regions and hence ensured food availability to the community. Likewise, 60% of the vegetables consumed in Dakar, Senegal were grown with a mixture of groundwater and untreated wastewater within the city limits (Faruqui *et al.*, 2004, cited by Ensink *et al.*, 2004a).

Buechler and Devi (2003), reported that in peri-urban and urban areas of India, the income generated by labour on wastewater irrigated fields and by the sale of produce contributed to the household food security for farmers utilizing the resource. In Pakistan, the impact of wastewater irrigation on household income was considerable as wastewater farmers earned approximately United States dollar (US$) 300 per annum more than farmers using freshwater (Ensink *et al.*, 2004b). In Nairobi, the average annual revenue per hectare from irrigated plots using wastewater was US$ 1770 while the average revenue per hectare for production around Kumasi was US$ 544 (Cornish and Kielen, 2004). The cash income earned enabled people to purchase food available in the market and thus ensured food availability to households (Buechler and Devi, 2003; Cornish and Kielen, 2004; Ensink *et al.*, 2004b).

2.8 Environmental Effects

The use of wastewater in agriculture has the potential for both positive and negative environmental impacts (WHO, 2006a). In most developed countries wastewater is treated before re-use while in many developing countries wastewater is used in agriculture both with and without treatment (Rashid-Sally and Jayakod, 2008). Municipal wastewater usually comprise of water with relative small concentrations of suspended and dissolved organic and inorganic solids (Pescod, 1992). It also contains a variety of inorganic substance from domestic and industrial sources, including a number of potential toxic elements such as heavy metals (Pescod, 1992). The components of wastewater that may have an impact on the environment include pathogens, salts, metals, toxic compounds, nutrients (nitrogen, phosphorus and potassium), organic matter, suspended solids, acids and bases. Mercury (Hg), Cadmium (Cd), Arsenic (As), Chromium (Cr), Lead (Pb) and Zinc (Zn) are common heavy metals which are found in almost any wastewater stream (WHO, 2006b).

Wastewater use in agriculture can pose environmental risks especially when untreated wastewater is used (Pescod, 1992; WHO, 2006b). Agricultural chain is the main source that can affect soil or water resources (WHO, 2006b). Early study by Pereira *et al.* (2002) indicated that pollutants accumulation in the soil as a result of wastewater irrigation may subsequently contaminate surface water and groundwater. Other studies (Mapanda *et al.*, 2005; Kinyashi and Obongoya, 2006) have shown that high concentration of heavy metals such as Cu, Zn, Fe, Pb and Cd in wastewater contribute to environmental pollution due to the fact that they are non biodegradable and generally do not leach from the top soil.

2.9 Heavy Metal Uptake by Plants

Heavy metals are a special group of trace elements which have been shown to create definite health hazards when taken up by plants (Okoronkwo *et al.*, 2005). Under this group are included, Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg) and Zinc (Zn) (WHO, 2006b; Okoronkwo *et al.*, 2005). The principle health hazards associated with the chemical constituents of wastewaters, therefore, arise from the contamination of crops or groundwater. The understanding of the behaviour of heavy metal in soil plant system seems to be particularly significant especially when the environmental quality of food production is an issue of concern (Chiroma *et al.*, 2003). The sources of heavy metal in plants are their growth media (air, soil, nutrients) from which heavy metals are taken up by roots (Okoronkwo *et al.*, 2005). Plant uptake of heavy metals depends on soil condition including pH, the presence of other heavy metals, organic matter content, the application of fertilizers, ploughing and water management (Chen, 1992 cited by WHO, 2006b).

A study conducted by Chiroma *et al.* (2003) indicated high concentration of heavy metals (Fe, Zn, Cu, Mg, Mn and Pb) in soil irrigated with sewage water and their accumulation in different parts of plants. The study further showed that the metal concentration varied in different parts of the plants. Drakatos *et al.* (2000), indicated that heavy metal concentrations in plant tissues are higher in the roots than in the leaves and fruits. Study carried by Rosen (2002) on metal accumulation to different parts of plants revealed that Pb does not readily accumulate in the fruiting part of vegetable and fruit crops such as beans, tomatoes and apples. It was further explained that higher concentrations are most likely to be found in leaf vegetables and on the surface of root crops.

Trend of occurrence of metal concentrations in plant samples differs. Earlier studies by Abdullahi *et al.* (2008) and Audu and Lawal (2005), on the concentration of Pb, Cr and Cd in different plant samples indicated that the occurrence of the heavy metals were in the order of Pb>Cr >Cd. This result suggested that plants had higher concentration of Pb and Cr than Cd. However, the literature reviewed does not provide information on the trend of heavy metal uptake by plants irrigated with treated wastewater from Waste Stabilization Ponds.

2.10 Wastewater Use and its Implication to Public Health

Use of untreated or partially treated wastewater for irrigation can pose a significant risk to public health and environmental degradation (Blumenthal and Peasey, 2002; Cornish and Kielen, 2004). People who face potential risks from the use of wastewater for agriculture are agricultural field workers, consumers and those living near irrigated fields (Buechler *et al.*, 2006; WHO, 2006b). Two case studies that examined the impact of untreated wastewater on health in Pakistan indicated higher hookworm infections among farmers and farm workers who used wastewater for irrigation than those who did not (Ensink *et al.*, 2004b). Vector studies carried out in Haroonabad and Faisalabad in Pakistan (Ensink *et al.*, 2004a) revealed that wastewater stabilization ponds and other wastewater bodies favoured the breeding of Anopheles and Culex mosquitoes which contributed to higher risks of vector-borne disease among poor communities that depended on wastewater use for their livelihood. Most of the vector-borne diseases can cause significant morbidity and even mortality in some cases (WHO, 2006c).

The use of wastewater containing a significant level of pollutants for irrigation may lead to metal accumulation in soils and crops. Human exposure to pollutants applied to soil through wastewater irrigation may take place through food-chain transfer of pollutants via the wastewater through soil, plant, human route and the consumption of grain, vegetables, root crops and fruit (WHO, 2006b). Plants grown in a polluted environment can accumulate the toxic metals at high concentration causing serious risk to human health when consumed (Okoronkwo *et al.*, 2005). The main risk for the public arises when crops grown are eaten raw (WHO, 2006b). The study conducted by Abdullahi *et al.* (2008) on the concentration of trace metals (Cd, Cr and Pb) in tomatoes and onions irrigated with polluted water of river Challawa, northern Nigeria indicated that both tomatoes and onions (exposed) had higher levels of the trace metals than the values recommended by Food and Agriculture Organization (FAO/WHO, 1993). The high levels of these trace metals in tomatoes and onions put the consumers of these crops at health risk.

2.11 Policy Aspects in Tanzania

The use of wastewater in agriculture has policy relevance in relation to poverty reduction, food security, protection of public health and environment in general (WHO, 2006a). The Tanzania National Water Policy of 2002 on urban sub-sector aims at achieving sustainable, effective and efficient development of urban water supply and sewerage services (URT, 2002a). The policy emphasizes on water resource management to ensure that water does not become a constraint to national development. Effectiveness and efficiency of water resource utilization in the country is one among the specific objectives of water resource management. The Tanzania National Water Utilization Act of 1975 and its amendment of 2001 have the function of controlling and setting standards for clean and wastewater resources including effluent from WSPs (URT, 2002b). The National Environmental Management Act of 1981 functioning through the National Environmental

Management Council (NEMC) monitors and regulates industrial and all other sources of pollution across the country (NEMC, 2006). The National Environmental Management Act No.20 of 2004 direct LGAs to ensure that the wastewater produced are appropriately treated before they are discharged into receiving water bodies. Under this Act, LGAs have been given mandate to prescribe and issue guidelines on how liquid wastes from domestic and commercial premises can be treated and finally disposed of both within the site and outside the premises (NEMC, 2006).

The Tanzania Development Vision 2025 provides the guiding framework for sectoral policies. Specific targets include: a high quality livelihood, which is characterized by sustainable and shared growth (equity), and freedom from absolute poverty; good governance and the rule of law; and a strong and competitive economy capable of producing sustainable growth and shared benefits. In order for Tanzania to achieve its development vision, eradicate poverty and attain food security, water is one of the most important agents to achieve these objectives (URT, 2002a). Along with the Tanzania Development Vision 2025 is the National Strategy for Growth and Reduction of Poverty (NSGRP) which was launched in 2005. The NSGRP is committed to the MDGs targets for reducing poverty, hunger, diseases, illiteracy, environmental degradation and discrimination against women by 2015 (URT, 2005). The strategy is divided into three clusters which include growth and reduction of income poverty, improvement of quality of life and social well-being and good governance and accountability (URT, 2005). Wastewater is a potential resource which can contribute positively in achieving some of the goals under the mentioned clusters. The most relevant goals in the NSGRP to agricultural use of wastewater are: i) improving food availability and accessibility; ii) reducing income poverty of both men and women in urban areas; and iii) a safe and sustainable environment.

The Water Resource Management Act of 2009 identifies rivers, tributaries, lakes, swamp, springs, sea water and interface between sea water and fresh water to be the sources of water in Tanzania (URT, 2009b). Other sources mentioned in the Act include water from dams, ponds and reservoirs. The Act provides guidance for human activities near the water sources. All activities including agriculture must be conducted beyond sixty meters from a water dam, reservoir or any water source (URT, 2009b). Both the National Water Utilization Act of 1975 and its amendment of 2001 and the Water Resource Management Act of 2009 do not clearly indicate water from WSPs to be among the sources of water in the country (URT, 2002a; 2009b). Thus, the value and potential of this important resource have been neglected by water boards and district planners to the extent of not including it in their planning process (Buechler *et al.*, 2006).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Areas

The study was conducted in urban and peri-urban areas of Dodoma and Morogoro regions (Fig. 2). Dodoma region is located in the central plateau of Tanzania extending between latitude 4° and 7°30' to the South and between longitude 35° and 37° to the East (URT, 1997a). The region lies at about 1040 meters above sea level. Dodoma has a dry savannah type of climate that is characterized by seasonal and unreliable rains, with a long dry spell from late April to early December and a short wet season from early December to the end of April (URT, 1997a). The average precipitation is between 500mm to 700mm per annum and in Dodoma urban district in particular average rainfall is 570mm (URT, 2008). Morogoro region lies between latitude 5°55' and 10°0' to the South of Equator and longitude 35°23' to the East (URT, 1997b). It has bimodal rainfall with short rains starting in October to December. Long rains start in mid-February to May and the average precipitation is between 600mm to 1200mm per annum (URT, 1997b). Specifically, the study was conducted in three districts of Mvomero, Morogoro urban and Dodoma urban. Availability of WSPs owned by the UWSAs or public institution and activities which uses wastewater from the ponds were the major reasons for selecting the study areas. Logistic support was also another reason for selecting the named districts.

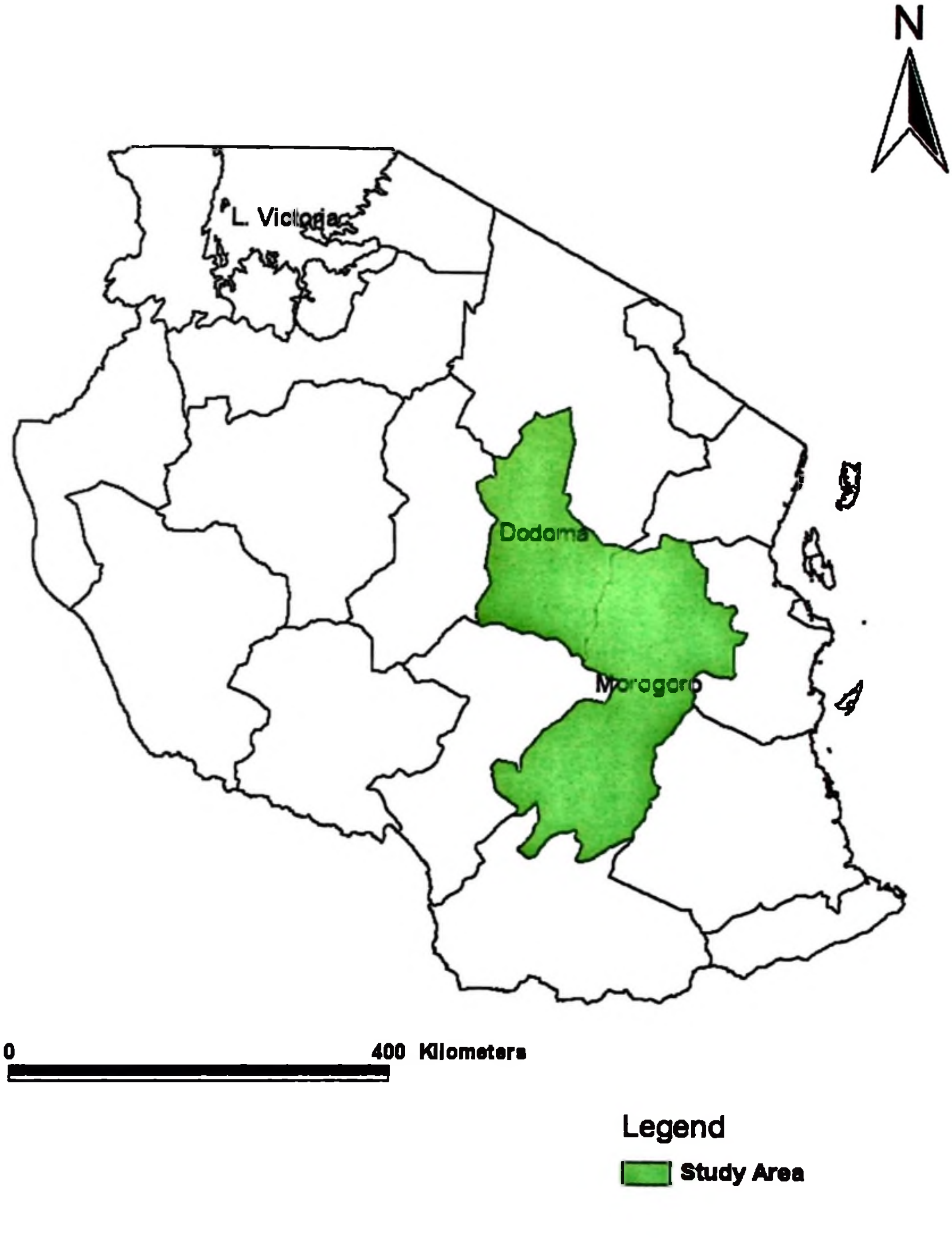

Figure 2: Map showing regions of the study areas

3.2 Study Design

The design for this study was cross-sectional which entails collection of in depth data of different groups of respondents at a single point in time (Bailey, 1994). Bryman (2004), explained that the design entails collection of data with the purpose of collecting a body of quantitative and/ or qualitative data about two or more variables which are then examined to detect patterns of association. Kayunze (2008), indicated that the design is justifiable as it is commonly used in the survey research to compare the extent to which at least two groups of people differ on the dependent variable. Samples of wastewater, sediments and plants were collected for analysis of heavy metals using chemical analytical methods.

3.3 Sample Size and Sampling Procedures

3.3.1 Sample size

The sample size for this study was 200 households. These were obtained by determining the proportion of households with access to sewerage connection in study areas. It was assumed that the same proportion would have access to the effluent from waste stabilization ponds. The sample size was computed using the formula:

$n = z^2 \times p \times q / e^2$ (Kothari, 1990) .... (1)

Where;

n= required sample size

z= standard deviation corresponding to 95% confidence level=1.96

e = desired degree of accuracy =0.05

p= proportion of households with access to sewerage connection =15%

q= proportion of households not having access to sewerage connection =85%

Hence, $n= 1.96 \text{x} 0.15 \text{x} 0.85/0.05^2 = 195$

The sample size computed was minimum and the author decided to add 5 households to make the overall sample size of 200 households. Also 24 government staff, three planning officers, two sewerage engineers, three officials from Urban Water and Sewerage Authorities, three health officers, nine extension staff, three street executive officers and one village executive officer were interviewed. Three street chairpersons, one village chairperson and 13 key informants were also interviewed. In each study area, 12 people were involved in a focus group discussion, thus making a total of 276 people involved in this study.

3.3.2 Sampling for questionnaire survey

The sampling frame for this study included all households in three selected streets in Dodoma and Morogoro urban districts and one selected village in Mvomero district where WSPs are located (Table 2).

Table 2: Sampling frame for the study

District	Ward	Street /Village	Number of Households
Dodoma urban	Makole	Swaswa Street	831
Morogoro	Mazimbu	Mazimbu Darajani Street	750
	Mwembesongo	Sina Street	925
Mvomero	Mzumbe	Changarawe Village	826
Total			**3332**

Multistage sampling technique was used that involved three stages. The first stage involved selection of two wards in Morogoro urban district, one ward in Dodoma urban district and one ward in Mvomero districts. In this stage, purposive sampling was used to select four wards. These wards were selected on basis of having WSPs. The second stage involved identification of street/villages which were close to WSPs. A list of streets/villages from each ward was prepared by assigning a unique card with number starting from 0 to provide a sampling frame. The cards for each ward were placed in a container and mixed up. From each container, two cards were randomly selected one after another. Following the advice of street/village chairperson and extension officers with regard to wastewater utilization in their respective areas, one street/village out of two selected was picked for this study. Finally, a list of households involved in agriculture was prepared with the help of street/village chairperson.

After identifying farmers who were involved in agriculture in the study areas, stratified random sampling procedure was employed to select 100 farmers from Dodoma urban district, 60 farmers from Morogoro urban district and 40 farmers from Mvomero district. This resulted into a sample size of 200 farmers for the study as a whole. Table 3 shows number of household sampled by street/village.

Table 3: Number of households sampled in study wards

Ward	Street/ Village	HH Not using wastewater	HH using wastewater	All HH Sampled
Makole	Swaswa Street	38	62	100
Mazimbu	Darajani Street	15	15	30
Mwembesongo	Sina Street	15	15	30
Mzumbe	Changarawe Village	20	20	40
Total		88	112	200

The WSPs in Mzumbe ward are meant to save the population of the Mzumbe University while those in Mazimbu ward are meant to save the population of SUA, Mazimbu Campus. Thus, wastewater from these ponds allows fewer farmers to engage in agricultural activities. Effluent from WSPs located in Mwembesongo ward in Morogoro urban district are discharged into river thus limiting the number of people who use the resource for irrigation purposes. Table 4 shows the distribution of respondents by wards.

Table 4: Distribution of respondents in the study wards

Ward name	Frequency (n=200)	Percent
Makole	100	50.0
Mazimbu	30	15.0
Mwembesongo	30	15.0
Mzumbe	40	20.0

3.3.3 Sampling of wastewater, sediments and plant samples

Sampling of wastewater, sediments and plants was carried out in Swaswa area located in Dodoma peri-urban area. Swaswa area is the most dependable source of vegetable production in Dodoma urban and peri-urban areas. The availability of a reliable source of water for irrigation makes Swaswa area famous for production of vegetable and other crops. Wastewater from Morogoro urban and Mvomero districts are discharged into the rivers, thus favouring production of crops which requires more water such as rice. Since the study intended to investigate levels of heavy metals in sediment and plant samples exposed to wastewater from WSPs (not diluted or mixed with river water), it was decided to take samples from Swaswa area in Dodoma urban district alone.

Water and bottom sediments samples were collected from five different sampling points (Fig. 3) that included Swaswa West (A) located about 50m adjacent to the inlet point in anaerobic pond (B), exit point in maturation pond (last pond in series of waste stabilization ponds) (C), Swaswa West located about 100m from the exit point in maturation pond (D) and Swaswa North located about 1200m from maturation pond (E).

Swaswa West (A) is a non wastewater irrigated site while Swaswa West (D) and Swaswa North (E) are wastewater irrigated sites. Sampling was done once during the dry season on 18 October, 2009 and all samples were collected in duplicates from each of the sampling point.

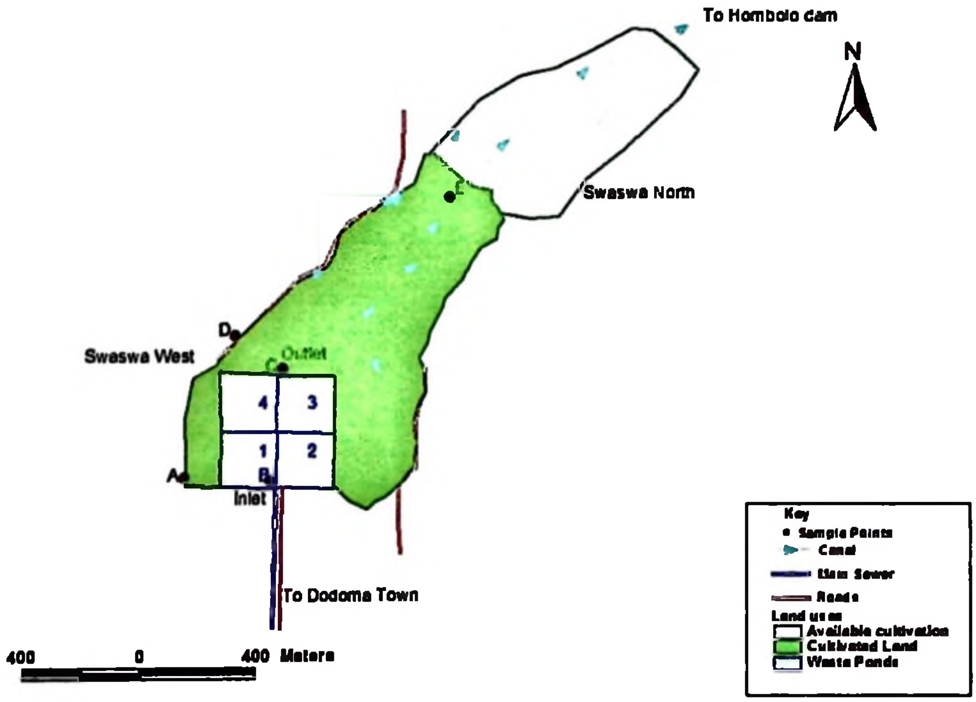

Figure 3: Sketch map showing water, sediments and tomato sampling points in Swaswa area, Dodoma, Tanzania

Sediment samples were collected at 0-15cm depth as heavy metals tend to be mobile only in the topmost soil layers (Tanji and Kielen, 2002). The depth was also considered to represent the plough layer and average root zone for nutrient uptake and heavy metals burden by plants (Samuel *et al.*, 2008). Stainless steel shovel was used to collect bottom sediment samples which were immediately placed in a labeled sterile sampling glass bottle about three-quarter full (Mdegela *et al.*, 2009). The remaining quarter was filled with water using the same stainless steel shovel from the same sampling point.

This was done with for the purpose of preventing oxidation. The samples were then packed in a cool box with ice packs and were moved to laboratory within 5 hours of their collection. Wastewater samples were collected by dipping sterile sampling bottles straight into wastewater. The pH of wastewater sample was determined and it ranged from 7.2 to 9.0. The pH was then adjusted to 2.0 using concentrated nitric acid (conc. HNO_3) by dropping 2 to 3 drops in a sterile bottle containing the sample. Collected wastewater samples were stored and transported to the laboratory as described for sediments.

Tomato samples were collected from wastewater irrigated gardens (Swaswa West located about 100m from the exit point in maturation pond, labeled (D) and Swaswa North located about 1200m from maturation pond, labeled (E)) and non wastewater irrigated garden (Swaswa West, labeled (A) located about 50m adjacent to the anaerobic pond) in a sterile sampling glass bottles separating the edible parts (fruit) from the non-edible parts (roots, stems and leaves) for heavy metal analysis. The separation of vegetables into edible and non-edible parts (Samuel *et al.*, 2008) aimed to establish the trends of heavy metal uptake from the soil to the roots/stems/ leaves and to the fruit of the vegetable. The samples were collected using a zigzag paths (zigzag sampling) to achieve randomness from each garden (Mapanda *et al.*, 2005). Collected samples were immediately packed in a cool box with ice packs. The samples were analysed in laboratory within 5h of their collection.

3.4 Sources of Data

Both primary and secondary sources of data were used in this study. Data from primary sources were obtained during a field survey conducted from 15 June, 2008 to 25 February, 2009. Primary data related to household characteristics, crop production, utilization of wastewater, perceptions of wastewater utilization including the benefits and problems associated with utilization of wastewater were collected by single visit interview (cross-sectional survey) to target groups by means of structured questionnaire and observation method. Secondary data from different sources such as government offices, official files and reports, and institutions were collected in order to complement the information obtained from formal survey.

Samples of wastewater, sediments and plants were collected, stored in a cool box with packed ice and were transported to the Southern and Eastern Africa Mineral Centre (SEAMIC) laboratory in Dar es Salaam, Tanzania for heavy metal analysis which included Mercury (Hg), Lead (Pb), Zinc (Zn), Chromium (Cr) and Cadmium (Cd).

3.5 Preliminary Survey

The preliminary survey was conducted between 15 March, 2008 and 10 April, 2008 prior to the operationalization of the main field work. The aims of the preliminary survey were: (i) to solicit background information about the study areas (ii) to familiarize with the study areas where the main survey was to be conducted (iii) to establish sampling frame and units (iv) to pre-test the questionnaire to ensure validity and reliability of the questions and data collection tools.

The structured questionnaire was pre-tested using 40 farmers in Mvomero and Morogoro urban districts. The experience gained during preliminary survey included among others: (i) Duration of the interview was not more than 60 minutes per questionnaire (ii) Some of the questions were not clear to the respondents. Corrections and adjustments were made to the data collection tools before actual data collection using the experience gained during the preliminary survey.

3.6 Data Collection Instruments

3.6.1 Questionnaire

Structured questionnaires were administered to a sample of 200 households who were engaged in farming activities close to WSPs. The structured questionnaires consisted of both open and closed ended questions. The questionnaire was designed to capture information related to wastewater utilization in agriculture. The questionnaire was made up of seven main parts in which the first and second part were designed to obtain general identification variables and background information on the characteristics of respondents; the third part was intended to obtain information on sources of water supply and wastewater production. The fourth part intended to get information on the utilization of wastewater followed by fifth part which aimed at identifying the potentials and problems of wastewater use. The sixth part was designed to gather information on crop production followed by livestock information. Part seven looked at the contribution of wastewater at household level. For more details about the questionnaire in terms of structure and contents see Appendix 1.

3.6.2 Focus group discussions

Focus group discussions (FGDs) covered the period between March and April, 2009. This method was used for data collection in semi-structured settings involving 10-12 people. The FGDs involved the two farmers groups and it aimed at getting information on the factors influencing the use of wastewater in agriculture and the benefits associated with the use of this resource. The FGDs permitted an opportunity to obtain details of person reactions and opinions. An interview guide for FGDs is appended to this research report as Appendix 2.

3.6.3 Checklist

Checklist of items for discussion with different officials was used to gather information concerning the district, wastewater production, the means used to treat wastewater produced and issues related to wastewater utilization. For more detail of the issues which were captured from government officials see Appendix 3.

3.7 Operationalization of Field Work

The field work for formal survey was conducted from June 2008 to February 2009. Before operationalization of field work, two enumerators were recruited and trained. Recruitment and training of enumerators were done with the aim of explaining the objectives of the study and some of the experience gained during preliminary survey and how to overcome them. Some of the experiences gained were reluctance of some of the respondents to be interviewed, worries and questions raised by respondents on the possibility of being asked to stop using wastewater.

The field work involved interviews with respondents using the designed questionnaires and discussions with key informants and government officials in the study areas using prepared checklists. Respondents were interviewed in their homes or in their agricultural fields after initial appointment which was done one day before the date of interview with the assistance of street/village chairpersons. The objectives of the study were explained to each respondent prior to interview to ensure understanding between the interviewee and interviewer. Respondents were interviewed once and their responses were recorded immediately.

Samples of wastewater, sediments and tomato plants were collected once from Swaswa area, Dodoma urban district in Tanzania on 18th October 2009 before it started raining.

3.8 Data Processing and Analysis

3.8.1 Data processing

The data collected was coded and entered into Statistical Package for Social Sciences (SPSS) for windows version 12, cleaned by running frequencies of individual variables and later analyzed. The SPSS was used to analyze most of the descriptive statistics. Cleaned data were later exported to other software package (Micro soft Excel) for generation of bar charts.

3.8.2 Data analysis

The large part of analysis for this study was based on descriptive statistics where frequencies, mean, mode, variance and correlation coefficients of some critical variables were determined. These statistics were used to assess respondent's characteristics, sources of water supply and domestic wastewater, extent of wastewater utilization in agriculture and its potentials. Cross tabulation was used to ascertain the correlations between different variables. The Chi-square test for independence was used to explore the relationship between two categorical variables that is farmers using wastewater in agriculture and those who were not using it. An independent sample - *t* test was used to compare the mean scores on some continuous variables. One way Analysis of Variance (ANOVA) was used to compare the variance between the different groups with the variability within each of the group. If the F- value was found to be statistically significant, a further test was performed to identify the means that were significant using Tukey Honestly Significant Difference (HSD) test technique.

Binary logistic regression model with a dichotomous dependent variable was used to determine the factors contributing to wastewater utilization. Binary or sometimes called binomial logistic regression is a form of regression which is used when the dependent variable is a dichotomy and the independent variables are of any type (Garson, 2008; Power and Xie, 2000). The model is used because it is a powerful and a popular one in social sciences at predicting a dependent variable on the basis of continuous and/or categorical independent variables, determining the percentage of variation in the dependent variable explained by the independent variables, ranking the relative importance of independent variables and understanding the impact of covariate control variables (Garson, 2008). The impact of predictor or independent variables is usually explained in terms of odds ratio (Garson, 2008; Power and Xie, 2000). Odds ratio for a given independent variable represents the factor by which the odd (event) change for a one-unit change in the independent variable (Garson, 2008).

According to Garson (2008), prediction of the dependent variable is done by computing the odds of the independent variable occurring. The percent of variation in the dependent variable explained by the independent variables is determined by computing Cox & Snell R Square and Nagelkerke R Square, which are analogous to the coefficient of determination (R^2) in Ordinary Least Square (OLS) regression (Garson, 2008; Power and Xie, 2000). Understanding the impact of independent variables on the dependent variable is done by observing the signs of the regression coefficients (B values), positive sign indicating positive impact on the dependent variable while negative sign indicates negative impact. The relative importance of individual regression coefficients (B values) for each independent variable is determined by observing the magnitudes of Wald statistics (Garson, 2008).

Thus, the model was specified as follows as suggested by Power and Xie (2000):

$\text{Logit}(p_i) = \log[p_i / (1-p_i)]$ ....(2)

Where:

Logit (p_i) = ln (odds) or (event), that is the natural log of odds of an event occuring

p_i = prob (event), that is the probability that an event will occur

1- p_i = prob (nonevent), that is the probability that an event will not occur

Equating equation 2 as a link function in the generalized linear model as suggested by Powers and Xie (2000), the logit model become

$\log [p_i / (1-p_i)] = \sum (\beta_k X_{ik} + \mu)$..(3)

Where;

X_i = represents set of independent (explanatory, predictor) variables

β_i = coefficients of the independent variables

μ = constant of the equation

Use of wastewater (dichotomous) was used as a dependent variable in the model and was coded 1 for a farmer utilizing wastewater and 0 for a farmer not utilizing wastewater. The independent variables used in this model were a mix of categorical and continuous variables. Age (AGE) and education (EDUC) of head of household, marital status (MARITAL), household size (HHSIZE), number of dependants in a household (NODEP), distance to main water source (DIST), location of a farmer (LOCAT), knowledge of a farmer in relation to the uses of wastewater (KNOW), awareness (AWARE) of the benefits of using wastewater, use of fertilizers in agriculture (FERTILIZER), crop production per acre (PRODACRE), awareness of the existence of bylaw regarding use of wastewater (ABL), size of a farm (FARMSIZE) and average income (AVERINCO) accrued from agricultural activities in one farming season were used as independent variables to assess how well they could predict or explain the categorical dependent variable.

An empirical logit regression model for farmer utilizing wastewater was thus specified as follows:

$$\text{Logit}(p_i) = \log[p_i/(1-p_i)] = \beta_0 + \beta_1 \text{AGE} + \beta_2 \text{EDUC} + \beta_3 \text{MARITAL} + \beta_4 \text{LOCAT} + \beta_5\text{HHSIZE} + \beta_6 \text{DIST} + \beta_7\text{FARMSIZE} + \beta_8\text{KNOW} + \beta_9\text{AWARE} + \beta_{10}\text{FERTILIZER} + \beta_{11}\text{AVERINCO} + \beta_{12}\text{PRODACRE} + \beta_{13}\text{ABL} + \beta_{14}\text{NODEP} + \varepsilon_i \quad (4)$$

In response to the specified model, the explanatory variables included in the model are summarized in Table 5.

Table 5: Specification of variables included in the model

Variable	Explanation	Measurability
AGE	Age of head of household	Years
HHSIZE	Household size	Numbers
EDUC	Number of years spent in school by the head of household	Years
MARITAL	Marital status of a farmer specified as "1" if a farmer is married, and "0" otherwise	Dummy
LOCAT	Location of a farmer in terms of district, "1" if a farmer lives in Dodoma district, and "0" otherwise	Dummy
DIST	Distance to reliable water source other than wastewater	km
FARMSIZE	Size of the farm under crop production	Acres
AVERINCO	Average household income accrued from agricultural activities in Tanzanian shillings (Tshs)	Tshs
KNOW	Knowledge on the uses of wastewater " 1" if a farmer classified as having knowledge and "0" otherwise	Dummy
AWARE	Awareness of the benefits of wastewater "1" if a farmer is aware, and "0" otherwise	Dummy
FERTILIZER	Use of fertilizers in agriculture specified as "1" if a farmer uses fertilizers, and "0" otherwise	Dummy
PRODACRE	Rice production per acre	Bags
ABL	Awareness of existence of by laws regarding wastewater utilization specified as "1" if aware and "0" otherwise	Dummy
NODEP	Number of dependants in a household	Numbers
Ut	Stands for wastewater utilization specified as "1" if utilizing wastewater and "0" otherwise	Dummy
β_i	Parameters to be estimated	Numbers
β_0	Intercept	Numbers
ε_i	Random error term	Numbers

In the analysis of the variables included in the model as specified in Table 5, knowledge on the uses of wastewater and benefits of wastewater were measured quantitatively using an index scale, which contained phrases implying that a farmer had knowledge on different uses of wastewater or were aware with the benefits of wastewater use if scoring not less than 60 marks out of 100 marks as illustrated in Table 6 and Table 7. The correct answer was awarded a maximum score of 10 points while a wrong answer was awarded 0 point

Table 6: An index scale for determining the knowledge on the uses of wastewater

	Points awarded	
Uses of wastewater	**Answer**	**Actual score**
Irrigation purpose (NO= 0; YES=10)		
Drinking water for livestock (NO=10; YES=0)		
Domestic uses (NO=10; YES=0)		
Source of water for forage irrigation (NO=0; YES=10)		
Fishing (NO=0; YES=10)		
Brick making (NO=0; YES=10)		
Construction (NO=0; YES=10)		
Car wash (NO=0; YES=10)		
Fertilizer (NO=0; YES=10)		
No use (NO=10; YES=0)		
Total score		

Table 7: An index scale for determining the degree of awareness of the benefits of wastewater

Benefits	Points awarded	
	Answer	Actual score
No benefit (NO=10; YES=0)		
Nutrients it contains (NO=0; YES=10)		
Reliable and cheap (NO=0; YES=10)		
High crop yield (NO=0; YES=10)		
Increase household food security (NO=0; YES=10)		
Source of income generation (NO=0; YES=10)		
Better household nutrition (NO=0; YES=10)		
Reduce costs of fertilizer (NO=0; YES=10)		
Preserving high quality water source (NO=0; YES=10)		
Source of employment (NO=0; YES=10)		
Total score		

Note that the scales were part of the household questionnaire as seen in Appendix I.

3.8.3 Heavy metal analysis in wastewater and sediments

Analysis of heavy metal in wastewater and sediments samples was carried out at the SEAMIC in Dar es Salaam, Tanzania. Water in sediments samples which occupied quarter of sterile sampling glass bottle was decanted and the remaining sediments were air dried in an air conditioned room set at 25°C and 65% relative humidity (Mdegela *et al.*, 2009). Sediment samples were further dried in an oven at 45°C for 48h and then milled using an Agate Planetary Micro-Mill (Fritsch). Dry powdered sediment weighing 0.5g were mixed with a mixture of 1.5ml concentrated hydrochloric acid (HCL) and 0.5ml concentrated nitric acid(HNO_3) (ratio 3:1) in a graduated test tube and digested on a hot plate reaching a temperature of 95°C. The mixture was allowed to cool to room temperature and then diluted with deionized water to 10ml mark. The mixture was left to react overnight (for at least 12h) and thereafter samples were ready for analysis of Hg, Pb, Zn, Cr and Cd using a flame atomic absorption spectrophotometer (Inductively Coupled Plasma (ICP-OES) ULTIMA 2 HORIBA JOBIC YVON, France).

Wastewater samples were measured directly for Hg, Pb, Zn, Cr and Cd by aspirating the filtered samples without any other treatment and therefore were analyzed as dissolved metals. Samples were analyzed for heavy metals using a flame atomic absorption spectrophotometer (Inductively Coupled Plasma (ICP-OES) ULTIMA 2 HORIBA JOBIC YVON, France).

3.8.4 Heavy metal analysis in tomatoes

Tomato samples (both edible and non-edible parts) were prepared for the analysis of heavy metals Hg, Pb, Zn, Cr and Cd (Samuel *et al.*, 2008). The raw samples were thoroughly washed to remove all adhered soil particles, initially with raw water and then with distilled water. The samples were then cut into small pieces and then dried in the oven at 70°C. The dried samples were ground in warm condition and passed through 1mm sieve. Well mixed samples of 1.0g each were taken into Teflon beaker. A mixture of 5ml concentrated nitric acid and 5ml perchloric acid was then added. The solution in the beaker was digested on low heat using hot plate for 15min at 70°C until light colored solution was obtained. The digest was allowed to cool. The digested sample was dissolved into 2ml concentrated nitric acid and then diluted to 50ml with deionized water. Samples were then analyzed for Hg, Pb, Zn, Cr and Cd using a flame atomic absorption spectrophotometer (Inductively Coupled Plasma (ICP-OES) ULTIMA 2 HORIBA JOBIC YVON, France).

3.8.5 Comparison of the analysed heavy metal levels with total daily intake

The total daily intake (TDI) for total mercury, lead, chromium and cadmium are 0.002, 0.0035, 0.00005 and 0.001 mg/kg body weight, respectively (WHO, 2008). According to Hassan and Ahmed (2002) the daily intake of green vegetable is considered to be 200g/person/day which is recommended amount from nutritional point of view. Tomato consumption in Dodoma urban and peri-urban community is 1-2 times a day and 7 days a week. This assumption was based on the information collected from women who had the responsibility of preparing meals in their households. Generally, 1kg of tomato was used to prepare four different meals in a household of 2-4 people. Based on this information, the study assumed that consumption of tomato in the study area was 0.125kg/person/day. An average body weight for an adult was considered as 60kg. The maximum acceptable residue levels (MARL) were calculated from TDI values using the following relationship:

$$MARL = \frac{\text{TDI (mg/kg body weight) x Body weight (kg)}}{\text{Amount of tomato consumed per day (kg)}} \qquad (5)$$

Health risk to consumers of tomato with different levels of heavy metals was investigated by comparing the maximum concentrations of heavy metals that were detected in tomato (fruit) samples with the MARL computed from Equation 5.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 Respondent's Characteristics

4.1.1 Respondents' status

Of the 200 respondents, 58.5% were males and 41.5% were females. The large proportion of male respondents in this study is attributed to the nature of study that required respondents to be interviewed in their fields and that most activities involving use of wastewater in agriculture were performed by men. Women are also involved in agriculture and related processing and selling activities (Mlozi, 1995). However, in most cases women are left at home performing households' reproductive and non-reproductive roles (Balihuta, 2001). Information with regards to marital status of head of households revealed that, of the 200 households heads, 71.5% of them were married, 14.5% were single and only 2% of them were divorcees (Table 8). With regard to respondents' status, 67.5% were head of households, 25.5% were housewife, 2.5% were daughters and 3.5 were son. Table 8 provides the summary of respondents' characteristics.

Table 8: Respondents' characteristics (n=200)

Sex of respondent	Percent
Male	58.5
Female	41.5
Households' head marital status	
Married	71.5
Single	14.5
Divorced	2.0
Widowed	12.0
Respondents' status	
Household head (Males and Females)	67.5
Housewife	25.5
Daughter	2.5
Son	3.5
Others	1.0

4.1.2 Age of households' head

The age (Mean ± SD) of households' head in Mvomero and Morogoro urban district were 42.5±10.7 and 38±9.9 years respectively, while in Dodoma urban district it was 39.7±11.6 years. However, the chi-square test indicated no significant difference ($p>0.05$). The minimum age in Mvomero, Morogoro urban and Dodoma urban districts were 25, 21 and 20 years respectively. The maximum age was 73 years in Mvomero and Morogoro urban districts and it was 67 years in Dodoma urban district. Table 9 shows the distribution of age in groups by district.

Table 9: Age distribution of households' head by district (n=200)

Age group (Years)	% Distribution by district		
	Mvomero (n=40)	Morogoro urban (n=60)	Dodoma urban (n=100)
20 - 35	35	46.7	41
36 - 50	45	43.3	39
> 50	20	10	20
Total	100	100	100

4.1.3 Educational level of households' head

The level of education of the households' head was generally low (Table 10). The majority (80%) of households' head in Mvomero district and Morogoro urban district indicated to have attained primary education with very few (7.5%) indicating to have advanced secondary education. About 12.5% and 15% of households' head in Mvomero district and Morogoro urban district indicated to have no formal education. In Dodoma urban district 66% of households' head indicated to have attained primary education while 26% indicated to have no formal education. This finding suggests that the level of education attained by households' head in the study areas did not differ much.

Table 10: Level of education attained by households' head by district (n=200)

Level of education	% Distribution by District		
	Mvomero (n=40)	Morogoro urban (n=60)	Dodoma urban (n=100)
No formal education	12.5	15.0	26.0
Primary education	80.0	80.0	66.0
Ordinary secondary education	7.5	5.0	5.0
Advanced secondary education	0.0	0.0	2.0
Diploma	0.0	0.0	1.0
Total	**100**	**100**	**100**

4.1.4 Household size

Table 11 presents the information with regard to household size in the study area. The findings indicate that mean household size (Mean ± SD) in Mvomero district it was 4.5 ± 1.7, in Morogoro urban district it was 5.0± 1.9 and Dodoma urban district it was 5.2 ± 1.7. The minimum household size was 1 for the three districts while the maximum number of household size was 9 in Mvomero district and 10 in Morogoro and Dodoma urban districts. The difference in household size between the three districts was insignificant ($p>0.05$) suggesting that the actual difference in household size was quite small. Comparing the finding of this study with the average household size reported by National Bureau of Statistics in 2000/01 which was 4.9 (URT, 2002c), it can be concluded that the rise in average household size for the past ten years was very minimal.

Table 11: Household size by district

Item	Mvomero	Morogoro urban	Dodoma urban
Mean	4.5	5.0	5.2
Standard Deviation	1.7	1.9	1.7
Minimum	1	1	1
Maximum	9	10	10

4.2 Assessment of Sources of Domestic Wastewater Production

4.2.1 Main source of water supply in the study areas

The study investigated the main source of water supply at household level as it has an implication on wastewater generation and consequently on the methods used to dispose wastewater produced at household level. The findings show that the majority of respondents from the three districts used piped water as the main source of water supply at household level. Of these, 82.5% of respondents from Mvomero district, 83.4% from Morogoro urban district and 87% from Dodoma urban district reported to have access to piped water as indicated in Table 12. These results show that there has been an increase in access to water supply in urban centres from 73% in 2005 as reported in NSGRP to more than 82% as found in this study.

Table 12: Percentage of respondents by main source of water supply at household level

Source	Mvomero district (n=40)	Morogoro urban district (n=60)	Dodoma urban district (n=100)
Piped	82.5	83.4	87.0
Spring	0.0	3.3	0.0
Wells	0.0	10	13.0
Rivers	17.5	3.3	0.0
Total	**100**	**100**	**100**

Clean and safe water refers to water obtained from a piped supply, or from a protected well (URT, 2002a). Though, 10% and 13% of respondents in Morogoro and Dodoma urban districts respectively reported to have been using wells as their main source of water supply, the FGDs revealed that the sources were not protected. Using water from unprotect sources expose people to water related diseases that not only cause high mortality, but also lower the productivity (SADC, 2002).

The results also show that 12.5% and 56.7% of respondents from Mvomero and Morogoro urban districts, respectively, obtained their water at a distance less than 400m from the place of residence. In Dodoma urban district, 36% of the respondents indicated to obtain water at a distance of 400m. This water supply coverage is not satisfactory and does not meet the goal set by the 1991 National Water Policy which aimed at providing clean and safe water to the population within 400m (URT, 2002a). Table 13 shows the distance traveled by respondents to the main water sources.

Table 13: Percentage of respondents by distance travelled to main water source

Distance in km	Respondent's district		
	Mvomero (n=40)	Morogoro urban (n=60)	Dodoma urban (n=100)
≤ 0.4	12.5	56.7	36.0
0.5 – 0.9	15.0	43.3	25.0
1.0 – 1.5	72.5	0	39.0
Total	**100.0**	**100.0**	**100.0**

From Table 12 and 13 it can be observed that though the majority of respondents indicated to use piped water for domestic purposes, the distance covered to reach the main source of water supply was still long as 72.5% and 39% of the respondents from Mvomero district and Dodoma urban district, respectively, obtained their water between 1.0 km and 1.5km whereas 43.3% of respondents from Morogoro urban district travelled between 0.5km and 0.9km to fetch water. Referring to 10 minutes as the average time taken to walk 400m (URT, 2003b), the above finding suggest that households spent 25-38 minutes to collect water. Walking long distances and spending more time for women, young girls and boys who are involved in water fetching activities in many places in Tanzania (Sagenge, 2007) has a significant effect on their socio-economic performance at their household level.

This reduces women's time spent for other productive activities, resulting into arriving late at work place, and for school age children arriving late or missing class sessions.

4.2.2 Sources of domestic wastewater production

The study investigated the main sources of domestic wastewater production in urban and peri-urban centers. Results from field survey and the FGDs conducted revealed that activities in residential, commercial and institutional areas were the major sources of domestic wastewater production in urban and peri-urban centers (Table 14). Findings show that 36% of all respondents indicated that activities that use freshwater at residential areas generate wastewater. The main areas that were pointed to be the source of wastewater production in residential areas include kitchen, bathroom/laundry and toilets. The findings also show that 27% indicated that institutions such as Hospitals, Schools, Police and Prisons generated wastewater as a result of their activities. Wastewater from commercial buildings was mentioned to originate from Hotels, Bars and Guest houses and it was reported by 25.5% of all respondents. Findings in Table 14 also show that 11.5% of respondents from the study areas mention other sources of wastewater production which included rainwater collected through open drainage systems and industries. Table 14 shows the sources of wastewater production in the study areas.

Table 14: Sources of wastewater generation in the study areas

Source	Percent
Residential	36.0
Institutions	27.0
Commercial	25.5
Others	11.5
Total	**100.0**

4.2.3 Wastewater disposal practices

The study investigated how domestic wastewater produced was disposed at household and at municipal level. Respondents were asked to mention the methods (s) which were used to dispose wastewater produced at their homes. At household level the findings show that the means of disposing wastewater produced varied from one individual to another. Table 15 shows the methods used by individuals to dispose wastewater produced at household level. Dug holes were mentioned to be the dominant method used by individuals to dispose wastewater as was supported by 181 out of 200 respondents. Of those who indicated to direct wastewater into dug holes, 20.4%, 28.8 % and 50.8% were from Mvomero district, Morogoro and Dodoma urban districts, respectively. Furthermore, the results in Table 15 show that individuals used pit latrines and septic tanks as a means of disposing wastewater generated at household level.

Table 15: Methods of disposing wastewater at household level

District	% of response directing wastewater into			
	Dug holes (n=181)	Pit latrines (n=57)	Septic tanks (n=53)	Storm drainage (n=13)
Mvomero	20.4	33.3	24.5	0.0
Morogoro urban	28.8	35.1	22.7	92.3
Dodoma urban	50.8	31.6	52.8	7.7
Total	**100.0**	**100.0**	**100.0**	**100.0**

Table 16 shows the type of toilets used by respondents in the study area by district, which is associated with the accessibility of water supply at household level. Findings in Table16 show that 77.5% of respondents in Mvomero district, 73.3% in Morogoro urban district and 74% in Dodoma urban district used pit latrines. Only 18.3% and 17% of respondents in Morogoro urban district and Dodoma urban districts respectively, indicated to have been using flush toilets. This finding suggests that people living in peri-urban areas primarily depend on pit latrines.

Table 16: Toilet facilities of respondents by district

Type	Mvomero (n=40)	Morogoro urban (n=60)	Dodoma urban (n=100)
Pit latrines	77.5	73.3	74.0
Improved pit latrine	22.5	8.4	9.0
Flush toilet	0.0	18.3	17.0
Total	**100**	**100**	**100**

At municipal level it was reported that the UWSAs are responsible for the provision of sewerage services to different customers. The UWSAs have complete system of piping, pumps, basins, tanks, unit processes and infrastructure for collection, transporting, treating and discharging of wastewater (WHO 2006b) which is commonly known as sewerage. The sewerage system consists of main/ trunk and lateral sewers connected to waste stabilization ponds. Individual customers are connected to lateral sewers which are then connected to the main sewer through chambers. However, coverage of the sewerage system in most UWSAs is reported to be less than that of water supply system thus covering a small proportion of the population (URT, 2007; 2008; 2009a).

According to URT (2009a), the available information indicates that the total length of sewer in Morogoro urban district is 30.2km with trunk/main sewer covering 9.7km and lateral sewers covering 20.5km. In Dodoma urban district, statistics shows that the total length of sewer is 55km out of which 24.3km is the main sewer and 30.7km is lateral sewers (URT, 2009a). Access to sewer connection was 13% and 15% in Dodoma and Morogoro urban districts respectively. This suggests that large proportion of population in

Dodoma and Morogoro urban districts depends on the on-site sanitation i.e. latrines and septic tanks. However, during field study it was observed that some efforts are being taken to increase coverage of sewerage infrastructure and the number of connections from houses to lateral sewers where the network is available.

Discussion with officials from UWSAs revealed that on-site sanitation services are implemented by the local authority or private operators. It was further noted that all domestic wastewater collected through sewerage system and cesspit emptier trucks are treated using WSPs. Treatment of wastewater is done by the use of natural factors such as sunlight, temperature, sedimentation and biodegradation (WHO, 2006a, b). The system of WSP comprises of anaerobic ponds, facultative ponds and maturation ponds which are linked in series (WHO, 2006a, b). Anaerobic digestion and sedimentation of organic wastes occur in the anaerobic pond which usually is the first pond in WSPs (WHO, 2006b). The Facultative pond is used to degrade organic matter and inactivate pathogens, while the maturation pond which is the final type of pond in WSPs system is responsible for removal of bacteria (WHO, 2006b). This information supports the findings by Ensink *et al.* (2007) that a system of waste stabilization ponds is recommended for wastewater treatment in arid and semi- arid developing countries.

4.3 Wastewater Utilization in Agriculture

4.3.1 Available sources of water for irrigation

Most of farmers in Tanzania depend solely on rainfall for production of food and cash crops (URT, 2001). The rainfall distribution in the country is not uniform and some parts of the country experience drought which affect the production of various food and cash crops, and pasture (URT, 2006). More than half of the country receives on average, less than 800mm of rainfall per year (URT, 2008).

Based on the fact that the rainfall in part of the study area was relatively low and unpredictable in frequency and amount (URT, 2006), investigation on different types of water available in the study area for crop irrigation was done. The results revealed that six sources of water were available in the study area as indicated in Table 17. Findings from Table 16 indicate that piped water, spring water and effluent from commercial building were mentioned by few respondents (less than 5% of all cases) to be the source of waster for irrigation in the study areas. The results also show that wells (30%), rivers (35.5%) and effluent from WSPs (87.5%) were mentioned to be the sources of water for irrigation.

Table 17: Available sources of water for irrigation

Water source	Frequency	% of cases
Piped	5	2.5
Spring	10	5.0
Wells	60	30.0
River	71	35.5
Waste Stabilization Ponds	175	87.5
Effluent from Commercial Building	9	4.5

Note: Computation of percentage are based on the number of cases, hence the percentage do not add up to 100

Further analysis was carried out to investigate the association between the water sources for irrigation mentioned by more than 10% of all respondents and the two groups of farmers included in the study (Table 18). Findings in Table 18 shows that 27.7% of farmers using wastewater and 33.0% of farmers not using it indicated wells to be the source of water for irrigation. However, the statistical association between the two groups of farmers and wells as a source of water for irrigation was not significant ($p>0.05$). Results in Table 18 also show that 22.3% of farmers using wastewater and 52.3% of farmers not using the resource indicated river to be a source of water for irrigation and the result was significant at $p<0.01$. Findings from Table 18 further show that 90% and 85% of farmers using wastewater and not using it respectively were of the opinion that effluent from WSPs was the source for irrigation and the difference was significant at $p<0.01$. This finding support the argument of Buechler *et al.* (2006) who noted that wastewater was a reliable source for plot irrigation and that it was available year round and not subjected to a rotation schedule as regular irrigation water.

Table 18: Sources of water for irrigation by type of farmers

Water source	% of farmers using wastewater (n=112)	% of farmers not using wastewater (n=88)	P value
Wells	27.7	33.0	0.419
River	22.3	52.3	0.000*
WSPs	90.0	85.0	0.001*

* = significant at $p< 0.01$

Investigation was further carried out on the type of wastewater used for irrigation for the group of farmers who were utilizing the resource. The results revealed that some farmers were utilizing untreated wastewater from sewer chambers before entering the waste stabilization pond which is the treatment facility for wastewater collected through sewer systems in urban areas (Ensink *et al.*, 2007). Out of 112 respondents who were using wastewater, 14.3% were using wastewater before it enters the waste stabilization pond. Of these, 85.7% were using effluent from waste stabilization pond which implies that they were using treated wastewater. An indication that some farmers were using untreated wastewater for irrigation shows that some farmers are not aware of the potential health impacts of wastewater utilization.

4.3.2 Irrigation technique used

Respondents in the group of farmer who were utilizing wastewater were asked to mention the method(s)/ technique(s) which they were using to irrigate their crops. A total of 112 respondents using the resource gave multiple responses as indicated in Table 19.

Table 19: Methods used to irrigate crops

Method used	Frequency (n=112)	% of cases
Flood irrigation	102	91.1
Bucket/ Perforated tins	82	73.2
Watering cans	7	6.3
Water pumps	3	2.7

Note: Computation of percentage are based on the number of respondents and not the total counts which is more than 112, hence the percentage do not add up to 100

Findings from Table 19 indicate that the majority of farmers (91.1%) irrigate their crops by flood irrigation technique. A possible explanation for the high percentage is that this technique has the lowest cost as it requires someone to have a hand- dug canal system to his/ her field and leveling of the field is not necessary. Through FGDs, it was revealed that the majority of farmers use this technique without wearing any protective gears such as gloves and boots. WHO (2006b) noted that fieldworkers are at highest risk when irrigating using wastewater without wearing protective clothing such as boots, shoes, and gloves. The findings also show that buckets and watering cans were also mentioned to be the methods used by farmers to irrigate their crops especially vegetables. Very few respondents (2.7%) indicated to have been using water pumps to irrigate their crops.

4.3.3 Person(s) involved in farm activities

Investigation was also made on people who are involved in farm activities using wastewater and in particular in irrigating crops. Respondents were asked to mention the people who normally irrigate crops and they were allowed to mention more than one if it was applicable. The findings show that members of the household and labourers were involved in the activity. The findings showed that 95.5% of the respondents claimed heads of household (including both males and females) to be involved in the activity. The findings also showed that other members of the household (30.4%) including daughters and sons participate in agricultural activities using wastewater. Furthermore, the findings showed that 26.8% of respondents indicated labourers to be involved in the activity, implying that it is a source of employment.

4.3.4 Acceptability of wastewater use in agriculture

Farmers were asked to give their opinion on the acceptability of using wastewater in agriculture. Both farmer groups were involved in providing their opinions. The finding showed that 97.3% of farmers using the resource indicated that using wastewater was acceptable. Of those who reported not to have been using wastewater, 64.8% indicated that using wastewater was acceptable, while 29.5% explained that using wastewater was not acceptable. The difference between farmer category and response on acceptability of using wastewater in agriculture was significant ($p<0.01$). This finding suggests that wastewater utilization is acceptable by both farmer groups involved in this study.

4.3.5 Land cultivated and acquisition

Respondents were asked to provide information on average size of land cultivated by household. The finding showed that the minimum size of land in acres cultivated was 0.25 and 0.5 for farmers using wastewater and not using wastewater respectively. The maximum size of land cultivated was 5.0 acres for farmers using the resource and 3.5 acres for farmers not using it. The difference in size of farm cultivated between the two farmer groups was insignificant ($p>0.05$). The possible explanation to this is that farmers engaging in agriculture in peri-urban areas possess plots of small size due to the fact that access to more land for crop production is limited.

Based on the above findings, further data analysis was carried to establish whether the size of land cultivated by farmers were significantly different between age groups of 20-35, 36-50 and above 50 years. The findings indicated that there was significant difference ($p< 0.05$) in size of land cultivated for the three age groups. Further comparisons of means using Tukey HSD test indicated that the mean size of land cultivated by age group 20-35 ($M=1.17$, $SD=0.55$) was significantly different ($p<0.05$) from age group 50+ ($M=1.62$, $SD=0.64$). The size of land cultivated by farmers in age group 36-50 ($M=1.40$, $SD=0.91$) did not differ significantly ($p>0.05$) from either group 20-35 or 50+.

Respondents were asked to mention how they acquired the land for crop production close to waste stabilization ponds. The findings show that 49.1% and 51.1% of farmers using wastewater and those not using it respectively, indicated to have personal or inherited plots. Of those who utilized wastewater, 31.3% rented the land for crop production while 19.6% were given by their relatives for a specific period. Table 20 present the summary of their responses with regard to modes of land acquisition.

Table 20: Percentage of respondents by modes of land acquisition

Mode of land acquisition	Farmers using wastewater (n=112)	Farmers not using wastewater (n=88)
Personal plots/ Inherited	49.1	51.1
Rented land	31.3	25.0
Given by relatives	19.6	23.9
Total	100	100.0

Through FGDs with farmers on the legality of cultivating close to WSPs, it was revealed that though farmers have been engaged in crop cultivation using wastewater for more than ten years the areas used were not zoned for agricultural purposes. Individual farmers cultivate land through informal arrangements with local leaders and representatives of the local authorities. These informal arrangements are temporary and farmers can be asked to quit the land anytime, sometimes without notice.

4.3.6 Type of crops cultivated

The study investigated the type of crops that were cultivated close to waste stabilization ponds in the three districts. Respondents gave multiple responses on the types of crops that were being grown in the fields close to wastewater stabilization ponds. Table 21 shows the type of crops cultivated by district. Findings from Table 21 indicated that 82.5%, 51.7% and 69% of farmers in Mvomero district, Morogoro urban and Dodoma urban districts respectively, cultivate maize. About 55% of farmers in Mvomero district and Morogoro urban district indicated to engage in vegetable production. In Dodoma urban district, 59% of farmers indicated to cultivate vegetables. Paddy/Rice production was reported by 60%, 70% and 53% of farmers in Mvomero district, Morogoro and Dodoma urban districts respectively. However, sorghum and groundnuts were mentioned to be additional crops grown by farmers in Dodoma urban district.

Table 21: Crops cultivated close to waste stabilization ponds by district (%)

Crop	Mvomero (n=40)	Morogoro urban (n=60)	Dodoma urban (n=100)
Maize	82.5	51.7	69.0
Rice	60.0	70.0	53.0
Sorghum	0.0	0.0	35.0
Vegetable	55.0	55.0	59.0
Groundnuts	0.0	0.0	27.0

Note: Computation of percentage are based on the number of respondents and not the total counts which is more than 200, hence the percentage do not add up to 100

Further investigation was also made on the type of crops cultivated in the study areas between the two farmers groups. The survey data in Table 22 reveals different types of crops cultivated by the two farmers groups. There was a significant difference ($p<0.05$) in maize cultivation closer to WSPs between respondents using wastewater and those not using it. Data in Table 22 also show that there was a highly significant difference ($p<0.001$) between the two groups of farmers and rice and vegetable being cultivated closer to WSPs suggesting that these crops are the main crops cultivated using wastewater. Results from Table 22 also show that sorghum and groundnuts were cultivated by small proportion of both farmer groups. No significant difference ($p>0.05$) was found between the two farmer groups in cultivating sorghum and groundnuts closer to WSPs. Hence, the main crops cultivated by farmers using wastewater in the study areas were maize, rice and vegetables.

Table 22: Crop cultivated by type of farmers

Crop type	% of farmers using wastewater (n=112)	% of farmers not using wastewater (n=88)	P value
Maize	58.9	76.1	0.01*
Rice	79.5	34.1	0.000**
Sorghum	12.5	23.9	0.06ns
Vegetables	83.9	23.9	0.000**
Groundnuts	14.3	12.5	0.874

*= significant at p< 0.05;
** = significant at p< 0.01

4.3.7 Different uses of wastewater

Investigation on different uses of wastewater was made for 200 farmers who could potentially have access to final effluent from Municipal and Institutions WSPs. Different uses of wastewater in the study areas are shown in Fig. 4. The result shows that 100% of farmers using wastewater and 87.5% of farmers not using the resource indicated that wastewater was used to irrigate crops such as maize, rice and vegetable. The other uses of wastewater mentioned by the two groups of farmers were brick making, construction of houses, domestic purposes other than drinking and cooking, drinking water for livestock, fertilizer to crops, fishing and forage irrigation.

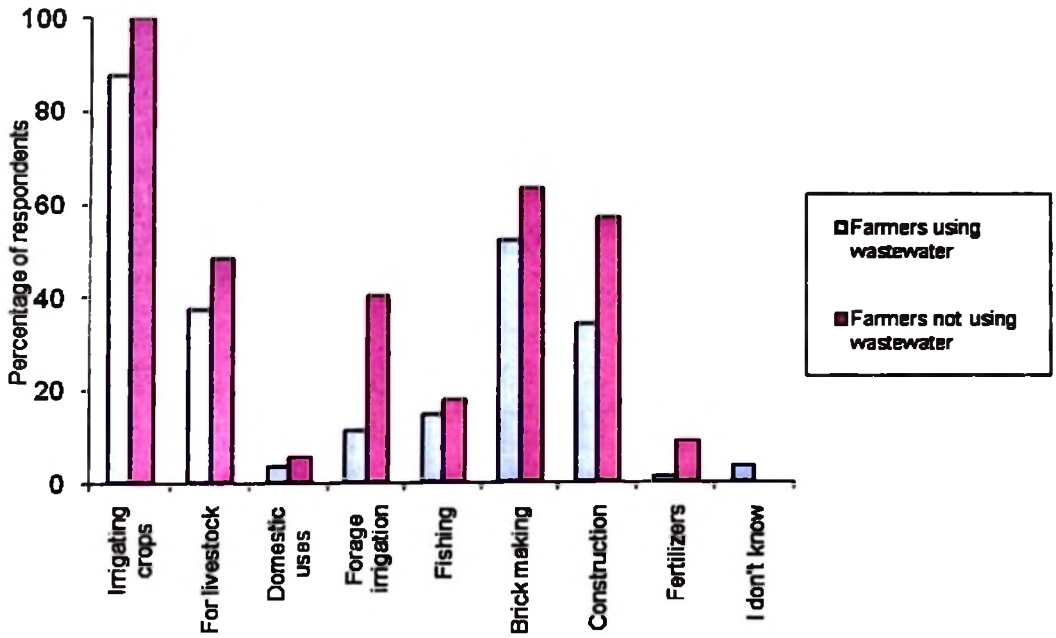

Figure 4: Different uses of wastewater

Based on the findings presented in Fig. 4, the chi-square test was carried out to determine the difference in proportion with regard to different uses of wastewater other than irrigating crops between the two groups of farmers. As presented in Table 23 there was no significant difference ($p>0.05$) between wastewater being used as drinking water for livestock and the two groups of farmers. Similarly, wastewater being used for domestic purposes, fishing and fertilizer between the two groups of farmers were found not to be significant ($p> 0.05$).

Findings from Table 23 shows that there was significant difference between farmer category and wastewater being used for forage irrigation ($p<0.001$). Findings also indicate that there was significant difference ($p<0.05$) between farmer category and wastewater being used for brick making. Wastewater being used for construction of houses was reported by 57.1% of farmers using wastewater and 34.1% of farmers not using the resource and the difference was significant ($p<0.05$). These findings suggest that apart from wastewater being used for crop irrigation, it is also used for forage irrigation, brick making and for construction of houses.

Table 23: Uses of wastewater and their respective p values

Type of use	% of farmers using wastewater (n=112)	% of farmers not using wastewater (n=88)	P value
Drinking for livestock	48.2	37.5	0.129
Domestic purposes	5.4	3.4	0.509
Fishing	17.9	14.8	0.560
Fertilizers	16.8	4.8	0.113
Forage irrigation	40.2	11.4	0.000**
Brick making	63.4	52.3	0.040*
Construction of houses	57.1	34.1	0.001**

* = significant at p< 0.05

** = significant at p< 0.01

4.4 Factors Influencing Wastewater Utilization

Different variables concerning the respondents were examined to check whether they had an influence on wastewater utilization in the study area. Comparisons were made between farmers who reported to have been using wastewater in agriculture and farmers who were not using it. The variables which were examined included age, education level and marital status of the farmer (head of houschold). Other variables looked at were the distance covered from homestead to a reliable water source and location where the farmer was carrying out his/ her agricultural activities. Farmers' views on the factors that influenced wastewater utilization were also considered.

4.4.1 Age of farmers

The mean age of farmers using wastewater was 38.9 ±11.9 while for those who were not using the resource it was 40.8 ±9.7 and the difference was not significant ($p>0.05$). Table 24 shows the age group distribution by type of farmers. Proportion-wise, most of the farmers were below 50 years of age. This finding suggest that majority of farmers in the study area were at economically productive age group.

Table 24: Age group distribution by type of farmers

Age group	% of farmers using wastewater (n=112)	% of farmers not using wastewater (n=88)
Between 20 and 35 years	46.4	35.2
Between 36 and 50 years	36.6	47.7
Above 50 years	17	17.1
Total	100	100.0

Since the difference in age between the two group of farmers was insignificant ($p>0.05$), more analysis was done under section 4.4.6 to determine whether age of the head of household had an influence on wastewater utilization.

4.4.2 Education level by type of farmers

Results from Table 25 indicate that most of farmers had attained primary education. Out of 112 household using the resource in agriculture, 75% had attained primary education and no one had attained post secondary education. On the other hand, out of 88 household heads not utilizing the resource, 70.5% had attained primary education. However, the number of farmers who had no formal education was slightly higher for farmers utilizing wastewater than their counterparts. This finding suggests that the level of education attainment was almost equal for the two groups of farmers. By considering the number of years spent in school by the heads of household, the variable was further subjected to analysis in section 4.4.6 to determine its influence on wastewater utilization.

Table 25: Education level by type of farmers

Education level	% of farmers using wastewater (n=112)	% of farmers not using wastewater (n=88)
No formal education	21.4	18.2
Primary education	75.0	70.5
Ordinary secondary education	3.6	8.0
Advanced secondary education	0.0	2.2
Diploma	0 .0	1.1
Total	**100.0**	**100.0**

4.4.3 Marital status of farmers

Table 26 shows that most of farmers in both groups were married with few of them divorced. The study noted further that for those farmers who reported to be single and widowed their proportion were close in both groups. It was for this reason that the Chi-square test was carried out to determine the difference in proportion with regard to marital status of farmers and farmers' category. The difference between marital status of farmers using wastewater was not significantly different (p>0.05) from farmers who were not using the resource. Further analysis was done under section 4.4.6 to determine whether marital status has influence on wastewater utilization.

Table 26: Marital status of farmers

Variable	% of farmer using wastewater (n=112)	% of farmer not using wastewater (n=88)
Marital status		
Married	71.4	71.7
Single	15.2	13.6
Divorced	2.7	1.1
Widowed	10.7	13.6
Total	**100.0**	**100.0**

4.4.4 Location of farmers

Table 27 shows that the proportion of farmers interviewed who were not utilizing wastewater in agriculture were relatively higher in Mvomero district and Morogoro urban district (Changarawe, Mazimbu Campus and Sina-Mwembesongo wards). In Dodoma urban district (Swaswa- Makole), the proportion of farmers using wastewater was higher (55.4%) than that of farmers who were not utilizing wastewater. Effluents from WSPs in Morogoro urban and Mvomero districts are discharged into rivers while in Dodoma urban district, effluents are discharged into ground (URT, 2007). These findings demonstrate that use of wastewater in agriculture is influenced by the location where farmers live.

Table 27: Location of farmers

Location / Ward	% of farmers using wastewater (n=112)	% of farmers not using wastewater (n=88)
Changarawe	17.9	22.7
Mazimbu Campus	13.3	17.0
Sina- Mwembesongo	13.4	17.1
Swaswa - Makole	55.4	43.2
Total	**100.0**	**100.0**

4.4.5 Farmers opinions on factors influencing wastewater use

Respondents were asked to give their opinions on the factors influencing wastewater use in agriculture. Age and level of education of head of household, household size, location of farmer where he/she lives, crop production, income accrued from activities involving use of wastewater and number of years that a farmer has been engaged in agriculture were mentioned as factors influencing use of wastewater in agriculture. Table 28 provides the summary of their responses with regard to the factors influencing wastewater utilization.

Table 28: Response on factors influencing wastewater use

Factor	Percentage
Age of household's head	9.5
Level of education of household's head	7.5
Household size	9.0
High crop production	26.5
High income	27.0
Geographical location	13.0
Experience in agriculture	7.5
Total	**100.0**

Age of a farmer was mentioned to have a direct relationship with the use of wastewater in agriculture. People with the age between 20 and 35 years were considered to be more energetic and therefore more likely to be involved in wastewater use. Furthermore, people in the said age group were considered to be the most economically active group and thus wastewater being available year round would enable them to generate more income. Table 24 indicated that 46.4% of farmers who reported to have been using wastewater were in the age group between 20 and 35 years and the remaining, 53.6% were farmers with age above 36 years. The study further examined the influence of age of a farmer in wastewater utilization when other factors are kept constant as seen under section 4.4.6 of this document.

Household size was another factor mentioned by farmers to influence the use of wastewater in agriculture. Large household size requires more food and more income in order to meet the basic needs. Furthermore, for large household size, the possibility of having enough manpower to work in agricultural activities is large compared to small household size (Simon, 2006). In this regard, large household size was considered to be a factor which causes a household to engage in activities that uses wastewater with the aim of increasing food availability.

Level of education of head of household was explained to have a relation with utilization of wastewater. Higher level of education of household heads was explained to have inverse relationship with wastewater utilization. It was argued that since wastewater found in stabilization ponds mainly comes from residential areas connected to sewerage systems, and that it contains mainly human excreta and used water, more educated people feel that the resource is dirty and not good for health. Fear of getting diseases as a result of direct contact with wastewater when irrigating was explained to be one of the reasons why educated people were not engaging much in using wastewater in agriculture. Further analysis on the influence of education on wastewater use was done under section 4.4.6.

Higher crop production for farmers who utilize wastewater in agriculture and saving in chemical fertilizer were explained to be the driving force behind wastewater utilization. This argument supported the finding of Ensink *et al.* (2004b) who noted that farmers using wastewater produced more crops per acre compared to farmers who were using regular water in their fields. Although farmers who utilize wastewater in agriculture posses small farms compared to their counterparts, crop production per acre was explained to be higher. Further discussion with farmers who utilize wastewater revealed that they use less to no chemical fertilizers in their fields.

The survey data for 108 farmers who utilized wastewater in agriculture in 2006/2007 indicated that 69.4% did not use any chemical fertilizer in their fields. About 52.5% (n=80) of farmers who were not using wastewater in 2006/2007 indicated to have used chemical fertilizer in their field.

Farmers utilizing the resource are able to harvest twice a year. During rain season, it was explained that crops such as maize, sorghum and rice are cultivated in their fields. After harvesting, it was reported that vegetables such as tomatoes, chinese, spinach, amaranth and okra were cultivated in large quantity for purpose of selling and home consumption. In view of this, farmers using wastewater were explained to be able to increase their income more than their counterpart.

Geographical location of a farmer where he/she lives was also mentioned to have an influence in wastewater utilization. Places where accesses to water sources are limited and which experience frequent periods of drought usually depends on wastewater as an alternative source (Buechler *et al.*, 2003; Ensink *et al.*, 2004b; WHO, 2006b). Referring to Table 27, Swaswa which is located in Makole ward in Dodoma urban district was found to have a higher number of farmers who were using wastewater compared to other wards which are in Mvomero district and Morogoro urban district. A plausible explanation of this is that the rainy season differs in different parts of Tanzania. While Dodoma region have only one rain season from December to March and long dry season, Morogoro region has two rain seasons (URT, 2008). Thus, limited access to reliable rainfall increases the likelihood of utilizing the resource in agriculture.

The number of years that farmers have been engaged in agriculture was mentioned to have influence on wastewater utilization. Farmers who have more than five years in agriculture activities and have farms close to treatment facilities were mentioned to be more involved in the use of wastewater in agriculture. However, it was mentioned that not all farmers cultivating close to WSPs have access to land every season. Some farmers did not have permanent farms and they were hiring at about Tshs 20 000/= to Tshs 40 000/= per season depending on the size of the farm. Based on this argument, information provided by respondents with regard to the number of years in agriculture was examined. Table 29 shows the number of years that farmers have been engaging in agriculture. Findings from Table 29 show that large proportion of farmers in both categories had experience ranging from 1 to 20 years. Results show that 93.6% of farmers using the resource and 94.2% of farmers not using the resource explained to have been involved in agriculture between 1 to 20 years and the difference was not significant ($p>0.05$). This result suggests that experience in agriculture has no influence on the utilization of the resource.

Table 29: Number of years in agriculture

Number of years	Farmers using wastewater		Farmers not using wastewater	
	Frequency	Percentage	Frequency	Percentage
1 - 5	34	30.6	28	32.2
6 - 10	44	39.6	41	47.1
11 - 15	18	15.3	12	12.6
16 - 20	9	8.1	2	2.3
21 - 25	2	1.85	3	3.5
26 - 30	3	2.7	2	2.3
31 - 35	2	1.85	0	0.0
Total	**112**	**100.0**	**88**	**100.0**

However, results in Table 29 could be linked with Civil Service Reform Programme (CSRP) which started in 1992. The overall objective of CSRP was to achieve a smaller, affordable, well compensated, efficient and effectively performing civil service (URT, 1999). Retrenchment of government employees was done to achieve the overall objective of CSRP. In the implementation of the programme within eight years, there was a reduction of 27% of civil servants from 355 000 in 1992 to 260 000 in 2000 (Caulfield, 2004). Thus, large proportion of farmers being involved in agriculture over the past 17 years as found in this study could be attributed by those retrenched to transit to new occupation outside the public service in order to sustain their life.

4.4.6 Results of the Logit Model

Based on the results and discussion on farmers' characteristics and the opinion of farmers on the factors influencing wastewater utilization, the study employed a logistic regression model (Logit Model) to predict which factors among the ones discussed influenced the use of wastewater in agriculture. The predictor (independent) variables were a mix of continuous and categorical variables and it is from this fact that the logit model was selected to predict categorical outcomes with two or more categories.

4.4.6.1 Model prediction and summary

Before using the model for prediction, coefficient of predictor variables (β values) were assigned positive or negative values. This was done in order to test the stability of the model after prediction. The positive or negative signs show the positive or negative impact, respectively, on the dependent variable. The expected signs were then compared with the actual signs after model prediction. Variables which were expected to contribute positively toward wastewater utilization included MARITAL, LOCAT, DIST, AWARE, PRODACRE, AVERINCO, NODEP, ABL and HHSIZE. Variables which were expected to contribute negatively included AGE, EDUC, FARMSIZE, KNOW and FERTILIZER.

According to Power and Xie (2000), the results of the analysis without any of the independent variables used in the model serve as a baseline later for comparing the model when predictor variables are included. The result of model prediction showed that the model predicted the cases correctly at 57.4% ($p<0.05$). The Omnibus Tests of Model Coefficients which shows the goodness of fit indicated that the dependent variable was better explained by the set of variables used as predictors ($p<0.05$). Hosmer- Lemeshow Goodness of Fit Test result indicated a significant value of 0.99 which is larger than 0.05, indicating that the model was good. The Cox & Snell R square and Nagelkerke R square values which provide an indication of the amount of variation in the dependent variable were found to be 0.686 and 0.921 respectively. These values suggest that between 68.6% and 92.1% of the variability in the dependent variable was explained by a set of independent variables mentioned in Table 5.

4.4.6.2 Variables in the equation

Table 30 indicates the 14 variables that were included in the model and their respective significant values in the seventh column labeled Sig. The Wald statistics shown in fifth column indicates non-zero values, which signify presence of relationship between dependent variable and the explanatory variables (Power and Xie, 2000). Wald statistic corresponds to significant testing of b coefficients in Ordinary Least Square (OLS) regression. Wald coefficients associated with individual independent variables help us realise the relative importance of each independent variable. A bigger Wald statistic implies that the independent variable associated with it has high contribution to the occurrence of the dependent variable.

Table 30: Variables in the equation

Variable	Expected sign of β	β	S.E	Wald	df	Sig.	Exp(β)
AGE	-	-.308	.763	.163	1	.687	.735
EDUC	-	-.104	.220	.221	1	.638	.902
MARITAL	+	1.580	1.543	1.048	1	.306	4.853
LOCAT	+	4.192	1.830	5.250	1	.022*	66.153
HHSIZE	+	-.548	.461	1.415	1	.234	.578
DIST	+	5.810	1.942	8.949	1	0.003**	333.591
FARMSIZE	-	-.961	.644	2.225	1	.136	.383
KNOW	-	-1.615	1.338	1.457	1	.227	.199
AWARE	+	5.454	2.465	4.895	1	.027*	233.798
FERTILIZER	-	-5.939	1.813	10.735	1	.001**	.003
AVERINCO	+	3.285	1.060	9.607	1	.002**	26.703
PRODACRE	+	2.490	.725	11.811	1	.001**	12.062
ABL	+	2.168	1.904	1.297	1	.255	8.744
NODEP	+	.199	.690	.083	1	.773	1.220
Constant		-30.234	10.169	8.840	1	.003**	

* = Significant at $p< 0.05$
**= Significant at $p< 0.01$

It can be clearly observed from Table 30 that all the independent variables included in the prediction model have non-zero regression coefficients, which implies existence of relationship between the dependent variable and the independent variables. Close examination between second and third column in Table 30 indicates that the model was stable as the expected signs for β values was similar for 13 variables out of 14 used in the prediction.

Results from Table 30 indicates that out of 14 factors which were analysed, eight factors had positive correlation with wastewater utilization and the remaining six factors were negatively correlated to wastewater utilization. The factors which were positively correlated to wastewater utilization in the study area were marital status, location of a farmer where he/she live, distance from homestead to reliable water source, awareness of the benefits of using wastewater, crop production per acre, average income accrued from agriculture in one farming season, awareness of the existence of bylaw governing the use of wastewater and number of dependants in a household. Factors that were likely to minimize the use of wastewater in agriculture were age, education, household size, farm size, knowledge on the uses of wastewater and minimal to no use of fertilizer.

The coefficient of location of a farmer where he/she live (LOCAT) was statistically significantly ($p<0.05$) and increased the likelihood of utilizing wastewater. The Wald statistic 5.25 indicates high contribution of the variable for the occurrence of the dependent variable which is wastewater utilization. A possible explanation to this is that places which experience drought and receive less rainfall and have treatment facilities which pour their effluent into the ground as the case of Dodoma urban district, are more likely to have more farmers utilizing wastewater in agriculture.

Results in Table 30 also show that the coefficient of distance from homestead to reliable source of water (DIST) was statistically significantly ($p<0.01$) and increases the likelihood of using wastewater as supported by bigger Wald statistic of 8.949. A plausible explanation of this is that household with limited access to reliable water source are likely to experience water shortage than their counterpart. Thus, wastewater could be the best alternative to overcome the problem of water shortage in their fields.

The coefficient of awareness on the benefits of using wastewater (AWARE) was statistically significant ($p<0.05$). This suggest that, farmers who are conversant with the knowledge that wastewater coming from the WSPs are potential resource and who knows the positive benefits of using this important resource (WHO, 2006b) have a greater likelihood of utilizing it in agriculture. The bigger value of Wald statistic (4.895) as indicated in Table 30 support the above argument.

The use of fertilizer (FERTILIZER) was found to have negative relationship with wastewater utilization and its coefficient was significant ($p<0.01$) with Wald statistic 10.735 as indicated in Table 30. This finding suggests that, farmers reporting to use less to no fertilizers in their field had a higher probability of using wastewater. This result was expected as wastewater contains nutrients necessary for plant growth (WHO, 2006b, c; Buechler *et al.*, 2006).

Table 30 further indicates that the coefficient of crop production per acre (PRODACRE) had a bigger value of Wald statistic (11.811) indicating it has high contribution to the occurrence of the dependent variable. It was positively correlated with wastewater utilization and significant at $p<0.01$. A plausible explanation to this is that wastewater contains the nutrients necessary for plant growth (WHO, 2006b) and thus, farmers utilizing wastewater are more likely to produce more per acre than their counterpart with less or no use of chemical fertilizer.

The result in Table 30 also indicate that the coefficient of income accrued from activities that involves the use of wastewater (AVERINCO) was statistically significantly ($p<0.01$) and increased the likelihood of a farmer to utilize wastewater in agriculture (Wald statistic 9.607). This finding suggests that the difference in income between the two farmer groups influence the use of wastewater for farmers cultivating close to WSP.

Age (AGE), education (EDUC), marital status (MARITAL), household size (HHSIZE), farm size (FARMSIZE), knowledge on the use of wastewater (KNOW), awareness of existence of bylaw (ABL) and number of dependants (NODEP) in a household were not significantly different ($p<0.05$) between the groups. This finding suggests that age, education level, marital status, household size, farm size, knowledge, awareness of existence of bylaw and number of dependants in a household were not the major factors that influenced the use of wastewater in agriculture.

4.5 Benefits of Using Wastewater

In trying to identify what are the social and economic benefits which result from utilization of wastewater in agriculture, respondents were asked to mention different benefits which results from use of wastewater. Table 31 shows the benefits of using wastewater as mentioned by both farmer groups.

Table 31: Benefits of using wastewater by type of farmers (%)

Type of benefit	Farmers using wastewater (n=112)		Farmers not using wastewater (n=88)		Test statistic	
	Accepted	Rejected	Accepted	Rejected	Chi-square	p value
Nutrient to crops	38.4	61.6	26.1	73.9	2.817	0.093
Reliable and no cost	83.0	17.0	51.1	48.9	21.976	0.000
High crop yield	76.8	23.2	50.0	50.0	14.387	0.000
Improve food security	59.8	40.2	51.1	48.9	1.177	0.278
Increase income	86.6	13.4	61.4	38.6	15.640	0.000
Improve nutrition	27.7	72.3	22.7	77.3	0.402	0.526
Reduce cost of fertilizer	50.9	49.1	20.5	79.5	18.203	0.000
Source of employment	58.0	42.0	28.4	71.6	16.300	0.000

4.5.1 Nutrients for plant growth

Results from Table 31 indicate that 38.4% and 26.1% of farmers utilizing and not utilizing wastewater reported that wastewater contained nutrients which are necessary for plant growth. However, no significant difference ($p>0.05$) was observed between farmer category and the type of benefit mentioned.

4.5.2 Reliability of wastewater

Reliability of wastewater and costless when using the resource was reported to be another benefit of using wastewater in agriculture by the two farmer groups as indicated in Table 31. About 83.0% of farmers who utilized wastewater and 51.1% of farmers who did not utilize it in agriculture indicated that wastewater was a reliable source for crop irrigation and the difference was significant ($p<0.01$). This finding supports the finding by Ensink *et al.* (2004b) that reliability of wastewater was the main reason for its use.

4.5.3 High crop yield

Increase in crop production per acre especially for farmers utilizing wastewater was mentioned to be one of the benefits of using wastewater in agriculture. Findings in Table 31 show that 76.8% and 50.0% of farmers who utilized and who did not utilize wastewater, respectively, reported that high crop yield was another benefit of using wastewater and the difference was highly significant ($p<0.001$). To support the above finding, further analysis was done for 188 respondents who reported to have engaged in crop production for the year 2006/2007. Further data analysis was carried out to compare crop production per acre between the two groups of farmers. There was a significant difference ($p<0.05$) in crop production of paddy per acre for farmers utilizing wastewater (M=8.7, SD=2.6) and farmers not utilizing it (M=4.2, SD=1.5). These results show that farmers utilizing wastewater produced on average 4.5 bags of rice per acre more than farmers not utilizing wastewater.

4.5.4 Improving household food security and nutrition

Findings from Table 31 further show that 59.8% and 51.1% of farmers using and not using wastewater in agriculture respectively, indicated that improvement in household food security was another benefit of using wastewater. Furthermore, 27.7% and 22.7% of farmers using wastewater and farmers not using wastewater, respectively, indicated that better household nutrition is possible because the purchasing power becomes higher due to the income accrued through sale of produce from wastewater and the consumption of vegetables produced. However, the chi-square test showed no significant difference ($p>0.05$) for these types of benefits.

4.5.5 Increase in income

Increase in income for sales of surplus crops and vegetables for farmers who utilize wastewater was mentioned to be among the benefits of using wastewater in agriculture for farmers cultivating close to waste stabilization ponds. Results from Table 31 indicate that 86.6% and 61.4%% of farmers using and not using wastewater respectively, reported increase in income to be the benefit of using wastewater and the difference was highly significant ($p<0.001$). Further analysis on the income accrued from agricultural activity in one farming season showed a great variation between the two farmer groups. Results from an independent samples t test indicated that there was a significant difference ($p< 0.05$) in mean income between farmers utilizing wastewater and those who were not using it. Farmers using wastewater had an income (Mean ± SD) of Tshs 363 888 ± 222 148 in one farming season per acre while farmers not using the resource earned Tshs 101 940 ± 57 603 per acre. This result indicates that on average farmers using the resource earned Tshs 261 948 more than farmers not using the resource. These results support findings by Ensink *et al.* (2004b) that farmers in Pakistan who utilized wastewater earned approximately US$ 300/ annum per acre more than farmers not using wastewater in agriculture.

Based on the above findings in relation to difference in income between the two farmers groups, further analysis was carried out in order to establish whether the average income accrued in one farming season by household were significantly different between the different age groups of 20-35, 36-50 and 50 years and above. The analysis indicated no significant difference ($p> 0.05$) in mean income between the three age groups.

4.5.6 Source of employment

Findings from Table 31 also indicate that wastewater was explained to be the source of employment. About 58.0% of farmers who utilized wastewater and 28.4% of farmers who did not utilize the resource indicated that wastewater was a source of employment for some individuals who were temporarily employed to irrigate crops and in brick making. The result showed a highly significant difference ($p<0.001$) between farmer category and wastewater being a source of employment.

4.6 Quality of Water, Sediments and Plants

4.6.1 Heavy metal levels in water used for irrigation

Table 32 shows the heavy metal concentration in wastewater samples and water from the wells that are used for irrigation by farmers at Swaswa sites in Dodoma peri-urban area in Tanzania. All water samples from five sampling sites had heavy metal concentrations below WHO (2006b) accepted values of heavy metals for crop production with exceptional of Cd which showed higher levels in four sites. However, looking at individual sites, Swaswa West (A) was found to have higher concentrations of heavy metals than the others. Higher levels of Cd were detected in water samples from Swaswa West (A) and Swaswa North (E) at levels that were three times higher than the WHO (2006b) accepted values of heavy metals for crop production. In Swaswa West (D) the levels of Cd were below detection limit (BDL). Higher levels of Cd compared to WHO (2006b) accepted values for irrigation water that does not lead to crop damage were detected in Anaerobic (B) and Maturation (C) ponds. The higher concentration of Cd could be attributed to the run- off of fertilizers from the farm land, urbanization and its availability in the earth crust.

All water samples had total Cr levels BDL The low concentration of Cr could be attributed by absence of effluent from industrial activities flowing into Municipal sewerage systems and minimal use of chromium containing compounds such as fungicides as previously observed in other studies (Mdegela *et al.*, 2009).

Table 32: Heavy metal levels (mg/l) in water samples from Swaswa area

Name of site	Hg	Pb	Zn	Cr	Cd
Swaswa West(A)	BDL-0.13	0.13-0.48	0.03-0.16	BDL	BDL-0.03
Swaswa West(D)	BDL-0.06	BDL-0.26	BDL-0.03	BDL	BDL
Swaswa North(E)	BDL	0.14-0.17	0.01-0.06	BDL	BDL-0.03
Anaerobic Pond(B) (1st pond)	BDL-0.03	BDL-0.39	BDL-0.01	BDL	BDL-0.03
Maturation Pond(C) (last pond)	BDL-0.01	0.16-0.27	BDL-0.03	BDL	BDL-0.03
Threshold levels of heavy metal for crop production (WHO, 2006b)	-	5.0	2.0	0.10	0.01

4.6.2 Heavy metal levels in sediments from Swaswa irrigated sites

Table 33 shows heavy metal levels (mg/kg dry weight) in sediments from different sampling sites in Swaswa area (Fig. 2). In all sampling sites the concentrations of Hg and Cd were low suggesting that their presence could be attributed by natural sources such as soil erosion and weathering of rocks rather than anthropogenic sources such as industrial, mining and urbanization (Mdegela *et al.*, 2009). On an average Pb, Zn and Cr contents were 13.89, 13.94 and 22.95 mg/kg, respectively in Swaswa West (A), whereas corresponding values in Swaswa West (D) were 12.73, 17.58 and 10.89 mg/kg. In Swaswa North (E), on an average Pb, Zn and Cr contents were 4.84, 4.44 and 6.29 mg/kg. Sediments from anaerobic pond (B) contained on an average 3.3, 19.6 and 5.1 times higher amounts of Pb, Zn and Cr, respectively compared to sediments from Swaswa North (E). These results of chemical analysis indicate that heavy metal in soils decreases with distance from the source, controlled mainly by water movement and topography.

The results agree with the findings by Jung, (2008), which indicated that concentration of heavy metals in soils decreases as the distance from the polluted source increases.

Results from Table 33 also show that there were no appreciable variations in heavy metal concentrations for selected metals between sediments from Swaswa North (E) and that from Maturation pond (C). These results suggest that the concentration of heavy metals in soils after the Maturation ponds are due to natural sources such as weathering of rocks, soils and volcanic eruption rather than anthropogenic sources.

Different countries have their own sediment quality control regulations in aquatic ecosystem (Mdegela, 2006; Mdegela *et al.*, 2009). Todate, Tanzania lacks its own sediment quality guideline for pollutant concentration. It is from this fact, the study used the limit proposed by WHO (2006b) for pollutant concentration for comparison purposes. Based on this comparison, all sediments samples had lower levels of Hg, Pb and Cd than the maximum permissible pollutant concentration values proposed by WHO (2006b).

Table 33: Heavy metal levels (mg/kg dry weight) in sediment samples from Swaswa area

Name of site	Hg	Pb	Zn	Cr	Cd
Swaswa West (A)	0.15-3.22	9.06-18.72	5.91-21.96	5.74- 20.16	0.03-0.18
Swaswa West (D)	BDL-0.18	8.69-16.77	15.98-19.21	6.36-15.42	BDL-0.39
Swaswa North (E)	BDL	3.39-6.28	4.44-4.44	2.77-9.80	BDL-0.17
Anaerobic Pond (1st pond) (B)	0.35-1.38	10.92-20.68	84.12-90.14	23.68-41.09	0.35-0.46
Maturation Pond (last pond) (C)	BDL	3.92-4.24	4.02-5.23	9.66-10.37	BDL-0.22
Pollutant Concentration (WHO, 2006b)	7	84	-	-	4

Note: No guideline value for pollutant concentration that has been proposed for Zn and Cr.

4.6.3 Heavy metal concentrations in tomato plants

Table 34 shows heavy metal concentrations in tomato plants grown in Swaswa area in Dodoma peri-urban areas in Tanzania. The results show that the concentrations of metals in plant tissues in Swaswa West (A) were higher compared to Swaswa West (D) and Swaswa North (E). These findings suggest that as the concentrations of heavy metal in irrigation water increases (Table 34), the heavy metal concentrations in plant tissues also increases (WHO, 2006b).

Results from Table 34 also show that, in all three irrigation sites, Hg concentration in leaves and fruits were BDL. Furthermore, concentrations of selected heavy metals in the roots were higher than that in the leaves and fruits. No big variations were observed between metal concentrations in the roots and stem. These findings suggest that metal concentrations in plant tissues are higher in the roots and stem than in the leaves and fruits as reported previously by Drakatos *et al.* (2000). This suggests that root crops irrigated with wastewater are more likely to have more concentration of heavy metals thus putting consumers at health risk.

The trend of occurrence of the heavy metal concentrations in the tomato samples from Swaswa West (A), Swaswa West (D) and Swaswa North (E) with exceptional of Zn is in the order of Pb > Cr > Cd. This trend suggests that tomatoes have higher concentrations of Pb and Cr than Cd. These results support the findings by Abdullahi *et al.* (2008) and Audu and Lawal (2005) that plant samples have higher concentrations of Pb and Cr than Cd.

Table 34: Heavy metal levels (mg/kg) in tomatoes grown in Swaswa irrigated sites

Analyte	Swaswa West (A)				Swaswa West (D)				Swaswa North (E)			
	Rts	Stm	Lves	Frt	Rts	Stm	Lves	Frt	Rts	Stm	Lves	Frt
Hg	0.15	BDL	BDL	BDL	0.01	0.02	BDL	BDL	BDL	BDL	BDL	BDL
Pb	7.26	11.03	1.94	2.87	3.04	1.79	1.36	1.02	3.10	3.43	1.94	1.84
Zn	8.47	9.50	4.58	5.33	6.50	6.66	2.93	1.77	2.95	2.78	1.48	1.13
Cr	8.73	2.48	0.55	0.74	3.25	1.18	0.60	0.19	1.09	0.86	0.12	0.09
Cd	0.70	0.59	0.44	0.67	0.31	0.25	0.27	0.15	0.29	0.25	0.19	0.11

Note: Rts means Roots, Stm means Stem, Lves means Leaves and Frt means Fruit

4.6.4 Levels of heavy metal in tomato and its implications to human health

The TDI for heavy metal levels and the maximum acceptable residual levels in tomatoes cultivated in Swaswa area in Dodoma peri-urban are shown in Table 35. The levels detected in tomatoes cultivated in Swaswa West (D) and Swaswa North (E) was below the maximum acceptable residual limit (MARL). This finding suggests that there is no indication of health risks to consumers of tomatoes irrigated with wastewater after the maturation pond. The results also indicate that the levels detected in tomatoes cultivated in Swaswa West (A) were above the MARL. This finding suggests that there is indication of health risks to the consumers of tomatoes grown close to the anaerobic pond through the food-chain transfer of pollutants (WHO, 2006b). A plausible explanation is that in the system of WSPs, anaerobic pond is the source of pollutants and therefore through seepage the source of irrigation water close to the first pond can easily be polluted.

Table 35: Maximum acceptable residual levels (MARL) in tomatoes in Swaswa area

Name of site	Trace metal	Maximum levels detected(mg/kg fresh weight)	TDI (mg/kg body weight) (WHO, 2008)	[a]MARL (mg/kg fresh weight)
Swaswa West (A)	Hg	BDL	0.002	-
	Pb	2.87	0.0035	1.68
	Cd	0.67	0.001	0.48
Swaswa West (D)	Hg	BDL	0.002	-
	Pb	1.02	0.0035	1.68
	Cd	0.15	0.001	0.48
Swaswa North (E)	Hg	BDL	0.002	-
	Pb	1.48	0.0035	1.68
	Cd	0.11	0.001	0.48

Note: No health based guideline value has been proposed for Zn and Cr
[a]MARL calculated from TDI as

$$MARL = \frac{\text{TDI (mg/kg body weight) x Body weight (kg)}}{\text{Amount of tomato consumed per day (kg)}}$$

4.7 Summary of the Chapter

This chapter has explained the characteristics of the respondents who were involved in this study. Generally it has been noted that both male and females engaged in farming using wastewater for irrigation. There were no big variation between household size, age and education level of head of households engaged in farming using wastewater and those who were not using it. The findings have shown that most of farmers had attained primary education.

This chapter also indicated the main source of wastewater production in the study areas. The findings have shown that residential areas, institutions and commercial buildings were the sources of wastewater production. The findings also have shown that effluents from waste stabilization ponds, which are treatment plants for wastewater generated, were the main and reliable source of water for irrigation.

The chapter also has explained the factors which influence wastewater utilization in the study areas. The findings have shown that awareness of the benefits of using wastewater, average income accrued from agricultural activities, crop production per acre, distance traveled to the main water source, location of a farmer and minimal use of fertilizer were important factors determining utilization of wastewater in agriculture.

This chapter also has explained the concentration of heavy metal in sediments, water and plants irrigated with wastewater. Variation of heavy metal concentration in plant tissues in different parts of the plant irrigated with wastewater has been explained. The findings have shown that metal concentrations are higher in roots than in the fruit (tomato). The findings further showed that tomato samples collected from Swaswa area in Dodoma urban district had low concentration of heavy indicating no health risks to the consumers.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

The general objective of the study was to investigate the extent of domestic wastewater utilization for irrigation in Dodoma and Morogoro regions. More specifically the study intended to achieve the following objectives (i) Assess the sources of domestic wastewater production in the study areas (ii) Examine the extent of wastewater utilization in agriculture in the study areas (iii) Determine factors influencing utilization of wastewater in the study areas (iv) Identify benefits of using wastewater in agriculture (v) Assess the quality of water, sediments and plants irrigated with wastewater.

Data for the study were collected from a sample of 200 households in the study areas using a structured questionnaire. The sample comprised of 88 households not using wastewater for irrigation and 112 households using the resource for irrigation. In addition to questionnaire survey, an interview with key informants and FGDs were conducted to get more information pertaining to benefits of using wastewater in agriculture and the factors which influenced wastewater utilization in the study areas. In addition to the above methods, a laboratory work was done to analyse the quality of wastewater, sediments and plant samples. This chapter presents the conclusions and recommendations emerging from the major findings of the study.

5.1 Conclusions

(i) The present study on the extent of domestic wastewater utilization for irrigation in Dodoma and Morogoro regions has demonstrated that although the majority of farmers irrigate their crops using wastewater after the maturation pond, there are

The study has also demonstrated that there is no indication of health risks to consumers of tomato irrigated with wastewater after the maturation pond in terms of heavy metals. Moreover, there is an indication of health risks to the consumers of tomatoes irrigated with untreated wastewater.

(ii) The main sources of wastewater generation in urban and peri-urban areas were activities in residential, commercial and institutions. At household level wastewater was generated from kitchen, bathroom and toilets while hotels, bar and guest houses were sources of wastewater generation from commercial buildings. Hospitals, schools, police and prisons were institutions which produced wastewater in urban and peri-urban centres. Wastewaters generated were collected through sewerage systems and cesspit emptier trucks and conveyed to a system of WSPs where treatment takes place. However, coverage of sewerage system infrastructure in the study areas was small, thus causing large proportion of population in the study areas to depend on the on-site sanitation.

(iii) Findings from this study have indicated that effluent from WSPs was the main and reliable source of water for irrigation in urban and peri-urban areas. The work also has identified that both treated and untreated wastewater were used by farmers in irrigating their crops. Informal irrigation was practiced by all farmers with the majority of them using flood irrigation as a means of irrigating their crops without wearing protective gears. This indicates that field workers are at health risk due to direct contact with wastewater.

(iv) The study has demonstrated that the use of wastewater was acceptable by farmers using wastewater in agriculture and those not using it. The association between respondents' view on the acceptability of using wastewater and farmers' category was highly significant suggesting that wastewater use in agriculture is acceptable by the two farmer groups. No significant difference was observed in size of the land cultivated by farmers using wastewater and farmers not using it. Crops irrigated using wastewater includes maize, paddy and vegetables. Other uses of wastewater apart from irrigating crops include, brick making, forage irrigation and construction of houses. However, areas used for agricultural purposes using wastewater are not specifically zoned for that activity and are not included in district agricultural plans.

(v) Based on the logit model, factors that influence wastewater utilization in agriculture includes awareness of the benefits of using wastewater, average income accrued from activities that involves use of wastewater, rice production per acre, distance traveled to the main water source, location of farmers and minimal use of fertilizers in the field.

(vi) The findings from this study have indicated that wastewater is beneficial to farmers as it provides nutrients necessary for plant growth, it is a reliable source of water for irrigation, source of income and assure high crop yield to farmers. The findings also indicate that there has been an increase in income for farmers utilizing wastewater than their counterparts as a result of selling surplus crops and vegetables which are produced throughout the year. The study has further demonstrated that wastewater is a source of employment.

(vii) In regard to the quality of water, sediments and plants exposed to wastewater, the study has demonstrated that all water sample from Swaswa site in Dodoma peri-urban had heavy metal concentration below WHO (2006b) accepted values of heavy metals for crop production. This leads to conclusion that water in Swaswa area can be used for irrigation without causing damage to crops. The study has also shown that the concentrations of heavy metals in soil decreases as the distance from anaerobic pond (source of pollutants) increases. The findings of this study have further demonstrated that all sediment samples had lower levels of Hg, Pb and Cd compared to the maximum permissible pollutant concentration proposed by WHO (2006b). Thus, it can be concluded that soil in wastewater irrigated field in Swaswa area had lower concentration of heavy metal thus the transfer of pollutants to people via the food-chain may occur in very small quantities.

(viii) The findings of the study have demonstrated that as concentration of heavy metals in irrigating water increases, the metal concentrations in plant tissues also increase. Furthermore, concentrations of heavy metals in roots were found to be much higher compared to the leaves and fruits. Results of the chemical analysis in tomatoes have demonstrated low concentration of heavy metals compared to the recommended values by WHO (2006b) for irrigation sites after the maturation ponds, and higher levels of heavy metals for irrigation site near to the anaerobic pond. On this basis it can be concluded that there is no health risks to consumers of tomatoes cultivated after the maturation pond.

5.2 Recommendations

From the present study, the following recommendations are made:

(i) To the Urban Water and Sanitation Authorities

a) To ensure adequate and sustainable supply of water and proper disposal of wastewater generated in urban areas, the UWSAs in the country should ensure improved access to and quality of water and sewerage services through expansion and maintenance of the existing infrastructures.

b) Currently 19 UWSAs have been established in the country with 9 having WSPs for sequential treatment of wastewater using anaerobic and aerobic ponds. It is important for UWSAs lacking the service to design and construct new sanitation and waste disposal infrastructure with agricultural end-use in view.

c) According to the National Water Policy of 2002, all buildings located within 30 meters from the sewerage line should be connected to sewerage system. The study has demonstrated that the current sewerage network in Dodoma and Morogoro urban districts is low and is not fully utilized. It is recommended that UWSAs should mobilize and encourage more owners of houses in urban and peri-urban areas to subscribe to sewerage services where the network is available.

(ii) To Decision Makers and Planners at Local Government Authorities

Currently, the focus of decision makers and planners at local authorities is on wastewater regulation and treatment. Use of wastewater in agriculture is not given due respect. This might have been caused by lack of information concerning the importance of the resource and has resulted to the omission of this important economic activity in their development plans. The current study has generated information on where wastewater irrigation takes place, the reasons for and extent of its use and the socio-economic benefits derived from its use. It is therefore recommended that decision makers and planners should include this important economic activity in their planning. Planning and management of wastewater use in agriculture should base on socio-economic benefits, environmental and extent of potential health risks involved in wastewater reuse.

(iii) To the Government of Tanzania

There are currently no guidelines for permissible levels of trace elements and heavy metals in wastewater used for irrigation, sediments and plants in Tanzania. Furthermore, there are no policies and practices designed for safe use of wastewater. This suggests the need for the country through the Ministry of Health and Social Welfare, Ministry of Agriculture, Food Security and Cooperation, Ministry of Water and Irrigation and the Tanzania Bureau of Standards (TBS) to develop guidelines, policies and practices for safer wastewater use to maintain the livelihood benefits, but reducing health and environmental risks.

(iv) Research and Development Partners

a) Since informal irrigation was practiced by individual farmers in irrigating their crops thus putting some farmers at health risks, it is hereby recommended that the current irrigation technique be improved. This can be done by the government in collaboration with development partners through designing and construction of some form of fixed irrigation infrastructure aiming at improving productivity while minimizing health risks.

b) The present study collected information on the extent of wastewater utilization and examined the level of heavy metals in tomatoes irrigated with wastewater.

However, the study did not capture information concerning the types and number of different pathogens in wastewater used for irrigation which can be used to quantify risk. It is recommended that, more research on microbial analysis be carried out to establish evidence of health effects associated with the use of wastewater in agriculture from infectious agents. Furthermore, it is recommended that research on organic pollutants such as pesticides, hydrocarbons and biotoxins be conducted as they are also found in any wastewater stream.

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APPENDICES

Appendix 1: Questionnaire for households using and not using wastewater in agriculture

PART I: GENERAL IDENTIFICATION VARIABLES

1. Name of District...

2. Name of Ward ....

3. Name of Street ....

4. Interviewer's Name.......................................

5. Name of respondent...............................

6. Sex of the respondent............................

7. Relationship of the respondent with head of household............

8. Date of Interview..

9. Starting Time of the interview................................

10. Finishing Time of the interview.............................

PART II; GENERAL HOUSEHOLD AND HOUSEHOLD CHARACTERISTICS

Please circle appropriate answer(s) wherever applicable and fill in blank spaces

11. Sex of the head of household

    01= Female

    02= Male

12. Age of the head of household................ (years)

13. Marital status of head of household

    01= Married

    02= Single

03= Divorced

04= Widowed

14. Highest level of education attained by head of household

01= No formal education

02= Primary level std 1-7

03= Secondary level ('O' level) 1-4

04= Secondary level ('A' level) 5-6

05= Degree level

06= Other (Specify)............................

15. How many years did you spend in school............ (years)

16. How many people are in your household? (Including head of household) .....

17. How many people in your household are below 14 years and how many are above 65 years of age? ....

18. Main occupation of the head of household

01= Civil servant

02= Business man/woman

03= Farming

04= Retired officer with pension

05= Wage employment

06= Other (Specify)................................

PART III: SOURCES OF WATER SUPPLY AND WASTEWATER PRODUCTION

19. What are the main sources of water supply in your area?

01= Piped

02= Spring

03= Dam

04= Well

05=River

06= Other (Specify)..............

20. (a) Is the amount of water supply enough to meet the daily demand?

01= YES 02= NO

(b) If YES go to question number 21. If NO what do you do? ....

21. What is the distance from homestead to the main water source? ....

22. What are the main sources of water for irrigation?

01= Piped

02= Spring

03= Dam

04= Well

05=River

06= Effluent from Waste Stabilization Ponds

23. What are the sources of wastewater generation?

01= Residential areas

02= Institutions

03= Commercial buildings

04= Others (Specify)...............

24. What are the sources of domestic wastewater production at houschold level?

01= Water from the kitchen

02= Water from bath and/ or laundry

03= Water from toilets

04= Others (Specify)....................

25. How does the household dispose wastewater produced?

01= Directing wastewater into dug holes

02=Directing wastewater to pit latrines

03= Directing wastewater into septic tanks

04= Directing wastewater into storm water drains

05= Directing wastewater to municipal sewerage system

PART IV: WASTEWATER UTILIZATION

26. (a) Does wastewater flowing from waste stabilization ponds accessible for use to every member in the community? 01=YES 02=NO

(b) If YES, how is the accessibility?

01= Open/Free

02= Restricted

03= Other (Specify)..............

27. (a) Does the household have access to land for crop production close to wastewater irrigated sites?

01= YES 02= NO

(b) If the answer is YES, how is the accessibility?

01= Owned/ Personal plots

02= Hired plots

03= Temporary plots given for particular growing season

28. (a) Does the household use effluent from WSP (wastewater) for irrigation purposes?

01= YES

02= NO

(b) If NO why not and which type of water do you use to irrigate your crops?

(c) If YES, which type of wastewater do you use?

01= Untreated wastewater/ wastewater before entering anaerobic pond

02= Partially treated wastewater/ wastewater flowing after maturation pond

(d) What factors do determine the use of wastewater in agriculture?

01= Age of household's head

02= Level of education

03= Household size

04= High crop production

05= High income

06= Geographical location

07= Experience in agriculture

29. What is the size of the land that is irrigated using wastewater? ...... (acres)

30. Which technique do you apply in irrigating your crops?

01= Flood irrigation

02= Surface irrigation from a hand-dug canal

03= Buckets or perforated tins

04= Watering cans

05= Drip irrigation

31. Who applies the technique?

01=Myself

02= Laborers

03=Boys

04=Girls

32. While irrigating your crops, do you use any protective device such as rubber boots and gloves?

01= YES

02= NO

33. What are the main uses of domestic wastewater?

01= Irrigation

02= Drinking water for livestock

03= Domestic use

04= Source of water for forage irrigation

05= Fishing

06=Brick making

07= Construction

08= Car wash

09= Fertilizers

10= No use

34. Which period of the year does wastewater become more important and why?

....

PART V: POTENTIALS AND PROBLEMS OF WASTEWATER UTILIZATION

35. What are the benefits of wastewater utilization?

01= No benefit

02= Nutrient

03= Reliable and cheap

04= Higher crop yield

05= Increase household food security

06= Income generation

07= Better household nutrition

08= Reduce cost of fertilizers

09=Preserving high quality water sources

10= Employment opportunity

36. Which problems do you think could be associated with wastewater utilization?

01= No problem

02= Skin problem

03= Increase in vector-borne diseases

04= Soil erosion

05= Bad smell

06= Conflicts among farmers

07= Water logging

08= Health risks due to consumption of fish/ vegetables exposed to wastewater

09= Others (Specify).........................

37. How do you solve problems identified in question No. 36? ....

38. (a) Is wastewater use acceptable?

01=Acceptable

02=Not acceptable

(b) Give reasons for your answer in 38 (a) ....

39. Are you aware of existence of any rules, regulations or bylaws which govern the utilization of wastewater from WSP?

01=Aware

02= Not aware

03= I don't know

Part VI: CROP AND LIVESTOCK PRODUCTION

Crop production

40. (a) Does the household engage in crop farming? 01= YES 02= NO

(b) If YES what is the size of the land? .... (Acres)

41. For how long have you been engaged in crop farming? (Years)................

42. (a) Did you grow crops in your field during the 2006/07 season?

01= YES 02= NO

(b) If YES go to question 43. If No, give reasons and go to question no.45

43. Indicate the type of crops grown in 2006/2007 season and production

Crop	Acreage	Production (bags of 100kg)
Maize		
Rice		
Sorghum		
Groundnuts		
Vegetables		

44. (a) Did you apply fertilizer in your field? 01= YES 02= NO

(b) If the answer is YES, indicate the type and quantity of fertilizer used for the period 2006/ 2007

Type of fertilizer	Quantity (Kg)

45. On average how many crops do you harvest per year in your field?

(Mention those crops) ....

46. How do you describe the quality of the soil in your field?

01= Poor

02= Fertile

03= Very fertile

(b) Give reasons for your answer in 46 (a)..

46. (a) Do you grow vegetable? 01= YES 02= NO

(b) If NO, what are the reasons and go to question no. 48

01= Shortage of land

02= Shortage of water for irrigation

03= Other (Specify)...

(c) If YES, which vegetable did you grow in your field during the 2006/07 season?

Please fill in the table below

Type of vegetable	Area planted (Acre)	Main use of vegetable 01= Sale 02=Own consumption 03= Both
Tomatoes Spinach Amaranth Okra Capsicum annuum(Green pepper) Solanuum macrocarpon(Nyanya chungu) Other (Specify).........................		

47. (a) Did you apply fertilizer in your field? 01= YES 02= NO

(b) If the answer is YES, indicate the type and quantity of fertilizer used for the period 2006/ 2007

Type of fertilizer	Quantity (Kg)

48. (a) Is there any seasonality in vegetable production?

01= YES 02= NO

(b) If YES give reasons

01= Shortage of water

02= Limited of amount of rainfall

03= Engagement in other activities

04= Water logging during rain season

(c) If NO give reasons

01= Availability of rainfall year round

02= Availability of freshwater for irrigation year round

03= Availability of wastewater for irrigation year round

04= Availability of the land which is not water logged throughout the year

49. What are the main constraints in crop farming?...

Livestock production

50. (a) Do you keep livestock in your farm?

01= YES 02= NO

(b) If YES, please fill in the table below concerning the livestock you own.

If NO, go to question 54

Type of livestock	Number owned todate	Number sold in 2007/2008 season	Reason for sale 01=Buy grain 02=School fees 03=Health care expenses 04= Other (Specify)	Amount in Tanzanian shillings
Cattle Sheep Goat Pigs Chicken Other (Specify)				

51. What type of grass/crop residual that you use for your livestock

01= Maize strove

02= Rice straw

03= Sorghum strove

04= Fodder grass around WSP

05= Other (Specify)...............................

52. What is the main source of drinking water for your livestock?

01= Piped water

02= Well

03= Dam

04= Effluent from WSP

05= Other (Specify)...

53. (a) Are there any problems for your livestock arising from use of effluent/ fodder grass from WSP? 01= YES 02=NO

(b)If YES, indicate those problems...................................

Part VII: CONTRIBUTION OF WASTEWATER TO THE HOUSEHOLD INCOME

54. What is the main source of income for your household?

01= Formal employment

02= Business

03= Farming

04= Remittances

05= Other (Specify)...

55. Indicate the average income per year for your household

01= Below 40,000 Tshs

02= Between 40,000 and 100,000 Tshs

03= Between 101,000 and 500,000 Tshs

04= Above 500,000Tshs

56. On average, how much do you earn per season from sales of agricultural products from your farm............... (Tshs)

Key for determination of income:

- Estimate how much is obtained per week from sales of vegetables
- Estimate how much is obtained per week/month from sales of crop during harvest
- Estimates how much is obtained from livestock enterprise
- Estimates total cash(lump sum)

57. How do you spend the income generated from agricultural activities?

01= Education

02= Health

03= Food

04= Water

05= Others (Specify)..

Appendix 2: Guideline for Focus Group Discussion (10-12 people in a setting)

1. Major sources of water supply in the area
2. Reliability of the water sources
3. Are the water sources protected?
4. Sources of water for irrigation
5. Sources of drinking water for livestock
6. Main sources of wastewater production
7. Factors influencing wastewater utilization in the area
8. Use of protective devices such as boots and gloves when using the resource in agriculture
9. Potentials of utilizing wastewater in agriculture
10. Problems associated with wastewater utilization
11. Measures taken to solve the mentioned problems
12. Acceptability of using wastewater and the produce
13. Legality of cultivating close to WSP

Appendix 3: Guideline for Discussion with Key Informants

A: Items for Discussion with Sewerage Engineer and UWSA Officials

1. Major sources of domestic/ municipal/ institution wastewater
2. Disposal practices of wastewater produced.
3. Sewerage system in the municipal/ institution (Length of trunk sewer, length of lateral sewer)
4. Population saved by the sewerage system (Access to sewer connection)
5. Option for inhabitants lacking access to sewerage system
6. Quantity of wastewater generated per day
7. Type of treatment facilities available
8. Capacity of Wastes Stabilization Ponds
9. Functionality of the Wastes Stabilization Ponds
10. Number of Cesspit emptier trucks
11. Protection measures for field workers during cleaning of WSP
12. Control mechanisms of wastewater (Before and after the WSP)
13. Utilization of wastewater (Legal/ illegal)
14. Factors contributing to wastewater utilization from WSP
15. Perception of people toward wastewater utilization
16. Major constraints to wastewater disposal/ Sabotage if any and reasons for it
17. Education/ Awareness campaigns on health and environmental risks resulting from wastewater utilization to the community and field workers

B: Items for Discussion with Municipal Officials

1. General information concerning the municipal/ ward
2. Type of water sources in the ward/ village/street

3. Proportion of household in the ward having access to improved water source
4. Reliability of the available water sources in the ward
5. Sources of domestic wastewater production
6. Treatment of wastewater produced/ Disposal mechanism
7. Coverage of sewerage systems
8. Proportion of household connected to sewerage system
9. Factors contributing to wastewater use from Wastes Stabilization Ponds (WSP)
10. Perception of people toward wastewater utilization
11. Benefits of wastewater use
12. Problems associated with utilization of effluent from WSP
13. Bylaws/Policies with regard to wastewater utilization
14. Urban agriculture and land use planning
15. Education/ Awareness campaigns on health and environmental risks resulting from wastewater utilization to the community and field workers